PB81-238073

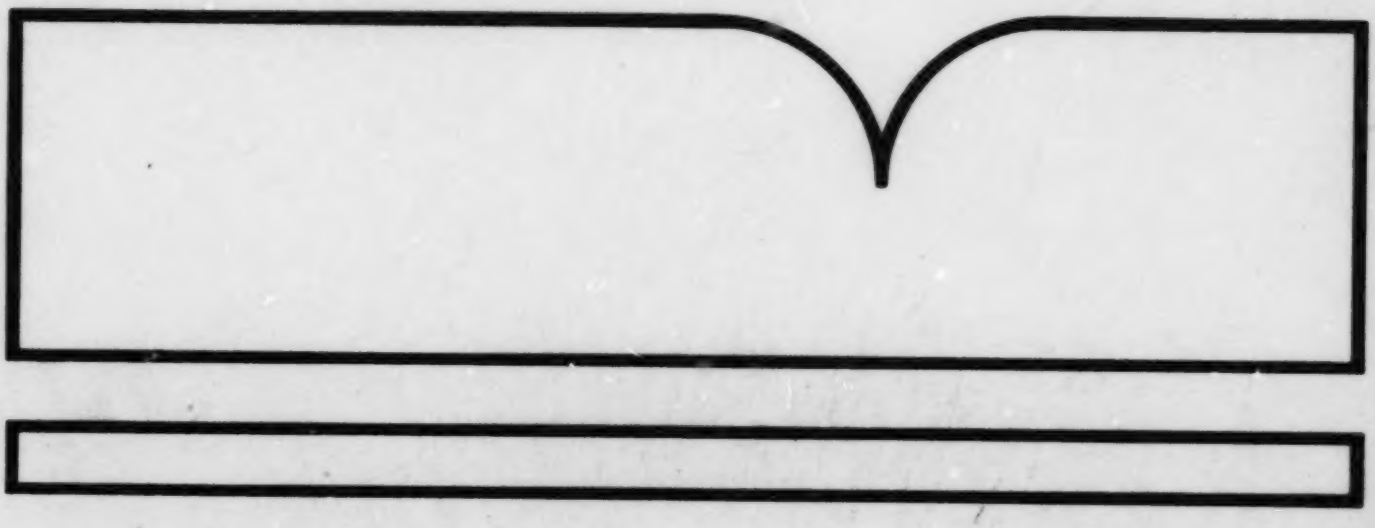
Soil Filtration of Sewage Effluent of a Rural Area

Colorado State Univ., Fort Collins

Prepared for

Robert S. Kerr Environmental Research Lab.
Ada, OK

Aug 81



U.S. Department of Commerce
National Technical Information Service
NTIS.

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
EPA-600/2-81-151	ORD Report	PB81 238073

4. TITLE AND SUBTITLE	5. REPORT DATE
SOIL FILTRATION OF SEWAGE EFFLUENT OF A RURAL AREA	August 1981
	6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
B. R. Sabey, K. A. Barbarick, and N. A. Evans	

9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT NO.
Department of Agronomy & Water Resources Research Institute Colorado State University Fort Collins, Colorado 80523	CAZB1B
	11. CONTRACT/GRANT NO.
	R805401

12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
Robert S. Kerr Environmental Research Lab - Ada, OK Office of Research and Development U.S. Environmental Protection Agency Ada, Oklahoma 74820	Final - 6/77 - 9/80
	14. SPONSORING AGENCY CODE
	EPA/600/015

15. SUPPLEMENTARY NOTES

16. ABSTRACT

The treatment performance of irrigation using primary lagoon treated municipal sewage is compared to normal stream or ditch water irrigation when applied to mountain meadows and crops in a high altitude climate during summer months. The two irrigation waters are applied at different rates to plots that have both natural drainage and tile underdrains. A special winter operation is evaluated for applying primary lagoon treated municipal wastewater to ridge and furrow basins after they have been covered with an insulating sheet of ice and snow. Development of winter operations allow capital cost of constructing winter storage to be drastically reduced for small rural treatment facilities.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Land use Sewage treatment Nutrient removal Soil water Ground water	Land treatment/sewage effluents Primary pretreatment Ridge and furrow basins High altitude irrigation Rural land use Underdrain systems	68D 43F 48B 48E 48F

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
RELEASE TO PUBLIC	UNCLASSIFIED	114
	20. SECURITY CLASS *(This page)*	22. PRICE
	UNCLASSIFIED	

EPA Form 2220-1 (9-73)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE
6-1/2"
9-1/8"
BEGIN LAST LINE OF TEXT
3/8"
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

PB81-238073

EPA-600/2-81-151
August 1981

SOIL FILTRATION OF SEWAGE EFFLUENT OF A RURAL AREA

by

B.R. Sabey, K.A. Barbarick, and N.A. Evans
Department of Agronomy
and
Water Resources Research Institute
Colorado State University
Fort Collins, Colorado 80523

R805401010

Project Officer

Lowell E. Leach
Robert S. Kerr Environmental Research Laboratory
Environmental Protection Agency
P.O. Box 1198
Ada, Oklahoma 74820

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA 22161

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE
6-1/2"
9-1/8"
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA. OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

DISCLAIMER

This report has been reviewed by the Robert S. Kerr Environmental Research Laboratory, U.S. Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

FOREWORD

The U.S. Environmental Protection Agency was established to coordinate the administration of major Federal programs designed to protect the quality of our environment.

An important part of the Agency's effort involves the search for information about environmental problems, management techniques, and new technologies through which optimum use of the Nation's land and water resources can be assured and the threat pollution poses to the welfare of the American people can be minimized.

The U.S. Environmental Protection Agency's Office of Research and Development conducts this search through a Nationwide network of research facilities. As one of the facilities, the Robert S. Kerr Environmental Research Laboratory is responsible for the management of programs including the development and demonstration of soil and other natural systems for the treatment and management of municipal wastewaters.

The slow-rate spray irrigation and ridge and furrow flooding processes for land treatment of municipal wastewaters use the unsaturated soil profile as the treatment medium during all seasons. In addition to the soil profile, the plants grown during summer months serve as a treatment medium through their metabolic assimilation of nutrients from the applied wastewater.

This project was designed to evaluate both treatment media during normal summer irrigation seasons and harsh mountain winters. Primary lagoon treated municipal wastewater is applied to high altitude mountain meadows using conventional spray irrigation techniques during summer months. The treatment capability of the unsaturated soil profile is evaluated during winter months using a unique ridge and furrow flood irrigation technique where wastewater is applied to furrows beneath an insulating cover of ice and snow. The results demonstrate a combination of the summer and winter operations can be a practical and cost effective alternative for upgrading municipal sewage treatment facilities for small rural communities. Upgrading costs are reduced by production of marketable cash crops and reduced storage requirements as a result of winter operations.

This report contributes to the knowledge which is essential for the U.S. Environmental Protection Agency to meet requirements of environmental laws and enforce pollution control standards which are reasonable, cost effective, and provide adequate protection for the American public.

Clinton W. Hall

Clinton W. Hall
Director
Robert S. Kerr Environmental Research Laboratory

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

ABSTRACT

The effects of sprinkler irrigated municipal sewage effluent and of surface tile drainage on a mountain meadow were investigated in the summers of 1977 and 1978. The treatments consisted of combinations of irrigations with effluent or ditch water at the rate of 7.5 centimeters/week (cm/week) and drainage tiles or natural drainage. Objectives of the field study were: (1) to investigate the removal by the soil-plant system of nitrogen, phosphorus, basic cations, organic material, and indicator organisms from the sewage effluent before the effluent percolates into the groundwater; (2) to determine the effects of the effluent on plant growth and quality; (3) to monitor the effects of the effluent on the soil properties; (4) to examine the need for drainage tiles; and (5) to determine the length of the application season. Before application, the effluent contained significantly higher levels of some water quality parameters than the ditch water.

The drainage tiles were effective in lowering the groundwater elevations for about 85% and 10% of the season in 1977 and 1978, respectively. Higher plant concentrations of sodium (Na) and manganese (Mn) in 1977 and plant yields and Mn concentration in 1978 were found in the plants harvested from the plots that were irrigated with sewage effluent. The influence of the effluent on groundwater quality and soil characteristics did not pose any health or environmental problems.

Another study to determine the feasibility of adding sewage effluent to mountain meadow land during winter was initiated in 1977 at Hayden, Colorado, near the summer effluent application site. This was motivated by the possibility of decreasing construction costs of sewage treatment facilities. Other objectives were: (1) to determine if 7.5 cm/week of effluent could be added under ice and snow on ridge and furrow configuration, and (2) to determine if size of ridges and furrows affected the application system or the effectiveness of filtration treatment, thus the groundwater quality and some soil biological and chemical properties.

It was determined that 7.5 cm/week of effluent could be added to the plots under an ice or snow cover if the soil profile was not frozen prior to ice and snow cover formation in the

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

late fall and early winter. The size of ridge and furrow configuration did not influence any of the biological and chemical parameters measured in the study. The winter soil filtration system was effective in decreasing the concentrations of some chemical constituents including ammonium (NH_4^+) and potassium (K^+), as well as decreasing biochemical oxygen demand (BOD), chemical oxygen demand (COD), and indicator organisms. The decrease in indicator organism numbers was not as great the second year of the study as it was the first.

In general, the effluent distribution system worked reasonably well even in the winter as long as rapid drainage of the pipes was provided at the conclusion of the application session of each day. The feasibility of adding effluent to the land has been demonstrated when weather conditions provided adequate snow covers prior to freezing of the soil profile.

6-1/2"
9-1/8"
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

CONTENTS

Foreword iii
Abstract iv
Figures viii
Tables ix
Abbreviations and Symbols xi
Acknowledgements xii

1. Introduction 1
   Summer Study 1
   Winter Study 3

2. Literature Review 4
   Current Status 4
   Macro Elements 5
   Trace Elements and Micronutrients 7
   Plant and Food Chain Effects 8
   Biological Aspects 9
   Physical Parameters 10
   Treatment Designs 10
   Collection Devices 11
   Management of Mountain Meadows 11

3. Conclusions 13

4. Recommendations 16

5. Materials and Methods 17
   Summer Study 17
   Winter Study 26

6. Results and Discussion 32
   Summer Study 32
   Winter Study 64

Bibliography 80
Appendices 89

6-1/2"
9-1/8"
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
Preceding page blank
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

FIGURES

Figure		Page
1	Plot design	19
2	Cross section, plot A	27
3	Cross section, plot B	28
4	Plot design - winter study	29
5	Hydraulic heads in the piezometer tubes for June 9, 1977	39
6	Hydraulic heads in the piezometer tubes for August 24, 1977	40
7	Hydraulic heads in the piezometer tubes for September 19, 1977	41
8	Groundwater elevations for June 2, 1977	43
9	Groundwater elevations for July 5, 1977	44
10	Groundwater elevations for September 10, 1977 .	45

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

TABLES

Number		Page
1	Vegetation species found in the mountain meadow used for land treatment of polishing pond effluent of Hayden, Colorado	2
2	Analyses of variance for data with a single sampling	24
3	Analyses of variance for data with multiple samplings	25
4	Range and average values for chemical characteristics of the two irrigation sources in 1977	33
5	Range and average values for chemical characteristics of the two irrigation sources in 1978	34
6	Mean values are statistics for 1977 for the chemical and biological data from all sampling locations	36
7	Mean values for statistics for 1978 for the chemical and biologica data from all sampling locations	37
8	Plant species distribution for 1977	47
9	Yield and hay quality parameters for 1977	48
10	Plant concentrations and total uptake of nutrients and metals in 1977	49
11	Plant species distribution for 1978	52
12	Yield and hay quality parameters for 1978	53
13	Plant concentrations and total uptake of nutrients and metals in 1978	54
14	Soil nitrogen	56

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE
9-1/8"
BEGIN LAST LINE OF TEXT
3/8"
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
PAGE NUMBER
EPA-287 (Cin.) (4-76)

Number		Page
15	Soil changes in total N, additions from irrigation and total plant uptake for 1977 and 1978 . .	59
16	Soil bicarbonate-extractable phosphates	61
17	Salts, pH, and exchangeable cations in the soil samples	62
18	Micronutrients and trace metals in the soil samples	65
19	Effect of winter applications of the effluent on chemical properties of the soils	69
20	Effect of winter application of effluent on chemical properties of the soil water	75
21	Effect of winter application of effluent on chemical properties of the soil water	76

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

LIST OF ABBREVIATIONS AND SYMBOLS

ANOVA	analysis of variance
B	boron
BOD	biochemical oxygen demand
°C	degrees Celcius
Ca	calcium
Cd	cadmium
Cl^-	chloride
cm	centimeter
Co	cobalt
COD	chemical oxygen demand
Cr	chromium
Cu	copper
DTPA	Diethylene triamine pentaacetic acid
DW	ditch water
EC	electrical conductivity
FC	fecal coliform organisms
Fe	iron
FS	fecal streptococcus organisms
g	gram
H	hydrogen
ha	hectare
HCl	hydrochloric acid
Hg	mercury
HNO_3	nitric acid
HSD^3	honest significant difference
ID	inside diameter
K	potassium
kg	kilogram
l	liter
m	meter
µg	microgram
mg	milligram
Mg	magnesium
ml	milliliter
mm	millimeter
mmhos	millimhos
Mn	manganese
Mo	molybdenum
MS	mean sum of squares
mt	metric ton or tonne
N	nitrogen
$\underline{N}$	normality
$\overline{Na}$	sodium
$NaHCO_3$	sodium bicarbonate
NH_4	ammonium
NH_4OAc	ammonium acetate
Ni	nickel
no.	number
NO_3	nitrate
OD	outside diameter
OH	hydroxide
P	phosphorus
Pb	lead
ppb	parts per billion
pH	-log 1/[H]
ppm	parts per million
PO_4	phosphate
α	probability level
$\propto$	proportionality
PVC	polyvinyl chloride plastic
SAR	sodium absorption ratio
SE	sewage effluent
SS	sum of squares
TC	total coliform organisms
ZE	zinc equivalent
Zn	zinc

BEGIN LAST LINE OF TEXT HERE
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.) (4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

ACKNOWLEDGEMENTS

The authors express appreciation to Lowell Leach, the Environmental Protection Agency Project Officer, for his assistance, encouragement and patience in the completion of this study.

Appreciation is also expressed to the EPA, the Northwest Colorado Council of Governments, the Upper Yampa Water Conservancy District, and the Colorado River Water Conservation Board for their financial support and encouragement. Additionally appreciation is expressed to the people of Hayden and Steamboat Springs for their help and interest.

Thanks are due to Cindy Baker, Randall Mutters, John Tessaderi, David Fanning, Brent Wilson, Kathleen Raddi, Kathyrn Beaumont, Paul Corey, Nick Young, and others assisting in laboratory and field work. Also the authors thank Mr. Dutch Williams and his family for the use of their land and in assisting in operation of the irrigation system during the study.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

SECTION 1

INTRODUCTION

SUMMER STUDY

The waste products that society produces will require disposal or recycling techniques that minimize contamination of the environment. Among these waste products are sewage sludges and effluents. Every municipality, regardless of size must treat and dispose of, or utilize, its sewage in some manner. Current alternatives range from secondary treatment involving anaerobic digestion, trickling filtration, aerobic digestion to lagooning and use of polishing ponds or combinations of these. Land application is being considered in many areas as a possible final treatment for effluent before it reaches a stream. For large cities, the more elaborate treatments may be more practical for handling the large volume of sewage; however, for small treatment plants in rural areas, the possibility of soil filtration as part of the treatment process could be more practical. Bouwer (1968) claimed that the quality improvement obtained by soil percolation is probably comparable to that obtained by coagulation, sedimentation, carbon adsorption, and disinfection.

Many studies have been conducted utilizing land treatment for disposal or recycling of municipal and industrial effluents. The study conducted at Hayden, Colorado was unique in two ways. First, it was conducted at high altitudes of the Rocky Mountain region. Secondly, it involved application of wastewater to mountain meadow type of vegetation (see Table 1).

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE
6-1/2"

TABLE 1. VEGETATION SPECIES FOUND IN THE MOUNTAIN MEADOW USED FOR LAND TREATMENT OF POLISHING POND EFFLUENT OF HAYDEN, COLORADO.

Common name	Scientific name
Red clover	*Trifolium pratense* L.
Orchard grass	*Dactylis glomerata* L.
Timothy	*Phleum pratense* L.
Bluegrass	*Poa pratensis* L.
	Poa compressa L.
Dandelions	*Taraxcum officinale* L.
White clover	*Trifolium repense* L.
Sweetclover	*Melilotus officinalis* L.
Alfalfa	*Medicago sativa* L.
Red fescue	*Festuca rubra* L.
Sedge-type grasses	*Carex* spp. (Dill.) L.
Western wheatgrass	*Agropyron smithii* L.

The effectiveness of land treatment depends on the quality and application rate of the sewage effluent and the soil characteristics. Consequently, the objectives of this research were:

1. To determine if the soil could effectively remove the problematic substances from municipal effluent before the filtrate entered streams, lakes, or groundwater. The major concerns were:
   a. Nitrogen (N) compounds such as nitrates (NO_3), ammonium (NH_4), and organic-N.
   b. Phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sodium (Na), iron (Fe), zinc (Zn), copper (Cu), and manganese (Mn).
   c. Biochemical oxygen demand (BOD), and chemical oxygen demand (COD).
   d. Fecal and total coliform and fecal streptococcus.
2. To follow the changes in soil properties created by sprinkler irrigation with sewage effluent.
3. To investigate the benefits of providing drainage in a "soil filtration" system.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

4. To determine if the yields and quality of hay produced by a mountain meadow irrigated with sewage effluent differed from those obtained from irrigation with typical irrigation water.

5. To determine the length of season during which sprinkler irrigation was feasible on mountain meadows at the altitude and latitude of Hayden.

WINTER STUDY

Application of sewage effluent to mountain meadows during the summer growing season appeared to be much more feasible than during the winter months where soils were more likely to freeze to a considerable depth and prohibit infiltration and permeability. If the soil surface and profile could be protected by the insulation of an ice sheet and/or a layer of snow, it could be possible to apply effluent by furrow irrigation under the snow and ice and still use the soil as a filtration system. This would allow a municipality to decrease the winter storage capacity and thus make land application more cost effective.

Although there have been many studies on the effectiveness of land application of sewage effluent in the eastern, central, and southern parts of the United States, few have been reported in the intermountain west. Only one study on winter application of effluent at higher altitudes was reported in the literature. That study involved the winter application of effluent from the sewage treatment plant of a cheese processing factory in Wyoming (Armstrong et al., 1978). No one had studied the soil filtration treatment of municipal sewage effluent during the winter season.

The objectives of the winter study were as follows:

1. To determine if it were possible to keep the soil profile unfrozen during the winter by forming a sheet of ice covered by snow over a ridge and furrow formed surface.

2. To determine if an effluent application rate of 7.5 cm/week could be maintained throughout the winter season.

3. To determine if the size of the ridges and furrows influenced the ease or difficulty of effluent application under the snow and ice.

4. To determine to what degree the soil filtration system of effluent treatment would decrease the content of several chemical and biological constituents of the effluent.

BEGIN LAST LINE OF TEXT HERE
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

SECTION 2

LITERATURE REVIEW

CURRENT STATUS

As might be expected, the application of effluents to land provide advantages and disadvantages. If the soil can reduce the concentration of undesirable substances to acceptable levels over a long enough season and over enough seasons, many communities will be able to treat their sewage without constructing expensive treatment facilities. Another advantage is that the land used for the disposal of the effluent will have not only a source of water for irrigation but also a source of plant nutrients, thus decreasing fertilizer needs (Bouwer, 1968; Bouwer and Chaney, 1974). One disadvantage is that the storage period each year is too long; the size of storage reservoirs may be prohibitive. Secondly, the capacity of the soil to remove particular substances may decrease after repeated applications of sewage effluent; therefore, additional land for disposal may be required. The quantity of the land required for disposal of the effluent will depend on the size of the community, the location of the treatment facilities, the quality of the soil and effluent as well as other factors. However, it is anticipated that soil filtration or land utilization of sewage effluent will be beneficial for many smaller communities in rural areas.

If the soil can effectively reduce the concentration of undesirable substances found in the sewage effluent from a polishing pond and if land is available for irrigation, many small communities could implement such a system instead of more elaborate and expensive treatment processes. A soil filtration system that is well designed will "cleanse" the sewage effluent while providing fertilizer for crop production for a considerable number of years.

Application of sewage wastes to the land to increase crop production has occurred in a number of different areas. Land disposal has been utilized in Australia, England, Israel, Germany, and various states in the United States (Dalton et al., 1968; Wilcox, 1948).

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

A majority of the constituents found in the sewage effluent of an average polishing pond do not meet the 1985 EPA standards for surface water quality (Bouwer and Chaney, 1974; Pound and Crites, 1973). Land application is considered by many as an effective but relatively inexpensive treatment process. The capacity of the soil to handle organic wastes may be determined by criteria discussed by Powers et al. (1975).

MACRO ELEMENTS

Organic-N, NH_4-N, and NO_3-N are the predominant forms of N found in sewage effluent and the soil. Various microbial transformations influence the concentrations of these forms of N. Organic-N can be mineralized to NH_4-N by a wide array of microorganisms. Ammonium can be transformed to NO_3 by the aerobic process of nitrification. *Nitrosomonas* and *Nitrobacter* catalyze this set of reactions. Nitrate may be converted to various N gases under reducing conditions by the process of denitrification. This process is accomplished by a number of anaerobic microoganisms (Alexander, 1977).

Soil columns that were intermittently flooded with sewage effluent over different time periods produced interesting results. A two-day flooding interval followed by five days of drying produced excellent conditions for nitrification (an aerobic process) as indicated by the high NO_3 concentration in the filtrate when flooding was initiated again. A nine- to 23-day flooding period followed by five-day drying cycles produced the greatest amount of N removal from the soil (e.g. by denitrification - an anaerobic process)(Lance and Whisler, 1972; Lance et al., 1973; Larson et al., 1975; Whisler et al., 1974). In a study in which soil columns were flooded for nine days and dried for five days, the organic carbon content of the sewage effluent and a decrease in the infiltration rate from 55 to 15 cm/day caused 80% of the N in the sewage effluent to be removed (Lance et al., 1976). Lance et al. (1978) also showed that the addition of plant clippings to the surface of the soil columns had essentially no effect on the removal of NO_3-N by denitrification.

Enfield (1977) found that adding sewage sludge to the surface of soil columns provided a carbon source that increased denitrification and resulted in an increase of 45 to >90% removal of solution N.

Another study indicated that NO_3-N leaching predominated early while N removal occurred later in the determination in a saturated environment (Tilstra et al., 1972). However, flooding periods greater than two days for most irrigated crop situations are impractical. Consequently, NO_3 contamination is possible if

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

N loads are greater than plant needs and the denitrification potential.

Other studies have investigated the NO_3-N levels in leachates or groundwater samples. Andrews and Troemper (1977) showed that samples from drainage tiles contained average monthly NO_3-N levels of 14.3 milligrams per liter (mg/ℓ) after sprinkler irrigation with liquid sewage sludge. This level is higher than the recommended standard for drinking water (U.S. Public Health Service, 1962). Hook and Kardos (1978) found that the application of sewage effluent with 7.3 mg N/ℓ at the rate of 5 cm/week to a hardwood forest site resulted in soil solution samples of >15 mg NO_3-N/ℓ at a depth of 120 cm. On an old cultivated site they found that 5 cm of sewage effluent/week rarely produced >10 mg NO_3-N/ℓ but 7.5 cm/week generally gave levels of >10 mg NO_3-N/ℓ at 120 cm. Groundwater samples from sites irrigated with cannery and milk wastewater contained 7 to 16 and 2 to 41 mg NO_3-N/ℓ, respectively (Adriano et al., 1975). In New Hampshire, Iskandar (1978) found that year round application of 15 cm/week of sewage effluent was not feasible since the leachate contained >10 mg NO_3-N/ℓ for more than nine months of the year. Spodosols in Florida were irrigated with sewage effluent, which contained 2.2 mg NO_3-N/ℓ and 14 mg Kjeldahl-N/ℓ, at the rate of 5 cm/week. Soil solution samples obtained from 60, 90 and 120 cm were found to have >1 mg NO_4-N/ℓ (Hortenstine, 1976).

Water hyacinths growing in ponds of secondary sewage effluent were found to be effective in removing N and P. The N and P removal was directly correlated to the surface area of the treatment ponds (Cornwell et al., 1977). Sutton and Ornes (1975) reported that 97% of the P in secondary sewage effluent was removed during the growth of duckweed in static wastewater.

Due to precipitation, adsorption, and plant uptake, the soil is effective in removing P. A number of studies showed that 94-99% of the P in wastewater was initially removed by soil filtration (Andrew and Troemper, 1977; Adriano et al., 1975; Beck et al., 1977; Iskandar, 1978; Tilstra et al., 1972). Kardos and Hook (1976) showed that higher concentrations of P in soil water samples were found at 15, 60, and 120 cm in soil irrigated with secondary sewage effluent. However, all concentrations were less than 1 mg/ℓ, and no site had leaching losses greater than 3% of the P applied. Attempts have been made to relate the movement of P from wastewater to the fraction of clay-size material present at the disposal site (Robbins and Smith, 1977) and to the sorptive capacity of the soil (Enfield, 1974). Sawhney (1977) indicated that several hundred pore volumes of sewage effluent had to pass through soil columns of Merrinas fine sandy loam and Buxton silt loam before the leachate concentration of phosphate (PO_4-P) reached that of the applied sewage effluent.

BEGIN LAST LINE OF TEXT HERE
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

The negative sites on mineral (clay particles) and organic colloids (humus particles) commonly found in soils provide electrostatic attraction for the positive cations such as K, Na, Ca, and Mg. This adsorption process reduced the mobility of these cations and the soil served for a period of time as an effective filter of these common constituents in effluents even though cations were still found in the filtrate (Henry et al., 1954). If the exchangeable (absorbed) Na percentage becomes high in a fine-textured soil with smectite clay minerals and low salinity, the percolation rates of the soil will be greatly reduced since Na would disperse the clay particles (Greenberg and Thomas, 1954; Henry et al., 1954; Lindsay, 1972; Stone and Merrell, 1968). This dispersion could reduce the lifetime of the "soil filter".

Most effluents contain relatively high concentrations of dissolved solids (salts) (Bradford et al., 1975). Laboratory studies (Appelt et al., 1975; Cassel et al., 1974; Ghuman et al., 1975) have been conducted to monitor solute movement through soils and accumulation in different horizons. Bresler (1967, 1973) has developed mathematical models that effectively predict the behavior of salts in soils. These studies could provide the background for predicting the effective lifetime of a land disposal system.

9-1/8"

Even though the soil does provide an excellent filter for most problematic substances in municipal effluent, reduction in chemical concentrations found in groundwater samples could be the result of dilution. Purtynam et al. (1977) found that reduction in salts, hardness, and various cations and anions could be attributed solely to dilution by a shallow aquifer.

TRACE ELEMENTS AND MICRONUTRIENTS

A wide range of trace element and micronutrient concentrations can be found in municipal and industrial effluents. These elements include Fe, Cu, cobalt (Co), Mn, Zn, chromium (Cr), Cd, nickel (Ni), molybdenum (Mo), lead (Pb), mercury (Hg), and boron (B), most of which can be toxic to plants at high soluble concentrations. These contaminants are absorbed by the reactive soil particles, precipitated as hydroxides (OH), carbonates (CO_3), oxides, sulfates (SO_4), or PO_4 or absorbed by plants (Lagerwerf, 1972; Lindsay, 1972, 1973). The trace elements and micronutrients as a general rule are effectively removed within the topsoil (Lehman and Wilson, 1971). However, most of the trace elements are relatively soluble and therefore mobile under acidic soil conditions (Griffin and Shimp, 1976; Griffin et al., 1976; Lindsay, 1972, 1973). Sidle and Kardos (1977a) showed that soil solution concentrations of Cu, Zn, and Cd were higher at a depth of 15 cm than at 120 cm. Attempts to model the transport of Cu, Zn, and Cd produced results which

BEGIN LAST LINE OF TEXT HERE
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE
6-1/2"
BEGIN LAST LINE OF TEXT
3/8"
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
PAGE NUMBER
F 'A-287 (Cin.) (4-76)

underpredicted the movement of these metals through the soil profile (Sidle and Kardos, 1977a, 1977b; Sidle et al., 1977). The underprediction was attributed to the lack of consideration for the "channelization" of the metals (Sidle et al., 1977).

PLANT AND FOOD CHAIN EFFECTS

The toxic constituents of greatest concern in sewage effluent that could be absorbed by plants are the trace elements. Those elements that pose potential hazards to the food chain include B, Cd, Co, Cr, Cu, Hg, Ni, Pb, and Zn (Bouwer and Chaney, 1974; Chaney, 1973). Chaney (1973) feels that Cd, Cu, and Zn could provide a significant hazard to the food chain. Chumbley (1971) expresses the hazard of Zn, Cu, and Ni as the Zn equivalent (ZE) where:

$$ZE = 1(Zn) + 2(Cu) + 8(Ni)$$

and the concentrations are expressed in parts per million (ppm). The ZE should be maintained at less than 250 ppm.

Chaney (1973) contends that only an effort to develop perennial grasses that would exclude toxic elements appears reasonable. Past work in which honeysuckle, reed canarygrass, and sea myrtle were irrigated with food processing wastewater (Luley, 1963) and bermudagrass was irrigated with secondary sewage effluent (Lehman and Wilson, 1971) indicated that grasses are relatively tolerant of the concentrations of trace elements commonly found in wastewater. Utilization of sewage effluent on crops where trace metals could be concentrated in edible portions must be thoroughly scrutinized. Bean, barley, and tomato plants grown in sand culture and irrigated with aqueous sludge extracts contained levels of B, Cu, Mo, Ni, Co, Pb, and Cd in leaf samples (Bradford et al., 1975) that were toxic to the plant. Various forest species showed no increase in the Cd concentration of the foliage on sites irrigated with secondary sewage effluent for ten years at Pennsylvania State University (Sidle and Sopper, 1976). Trace metal accumulations in soils were found to be greater on sites growing reed canarygrass than on areas growing corn (Sidle et al., 1976).

Irrigation with secondary sewage effluent can often influence the yield and quality of some small grains. Wastewater was found to produce a higher moisture content in oat forage (Day and Kirkpatrick, 1973); higher wheat hay yields, amino acid content and total fiber (Day et al., 1974); and higher wheat grain yields and more total protein (Day et al., 1975). Consequently, crops irrigated with wastewater may accumulate trace metals, but beneficial changes in crop quality may also occur.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

BIOLOGICAL ASPECTS

According to Miller (1973), the biological component of soils is of extreme importance in providing and maintaining the filtering aspects of soils. He states that microbes contribute significantly to the following five areas:

1. Decomposition of organic matter.
2. Detoxification of potentially hazardous organic substances (e.g., pesticides and detergents).
3. Removal of pathogenic organisms.
4. Participation in the N, P, and sulfur (S) cycles.
5. Influence on the solubility and mobility of inorganic ions.

Most pathogenic organisms have been found to be retained by the top few cm of soil (Miller, 1973; Bell and Bole, 1978). Andrews and Troemper (1977) discovered that 99%+ of the biochemical oxygen demand (BOD_5), suspended solids, and fecal coliform were removed before the wastewater percolated into drainage tiles. Similar results were shown in New Hampshire (Iskandar, 1978) and the Netherlands (Beck et al., 1977).

Before pasturing of alfalfa which was sprinkler irrigated with municipal effluent, ten hours of bright sunlight was required to remove fecal coliforms from the plants (Bell, 1976; Bell and Bole, 1978). With reed canarygrass, 50 hours of bright sunlight provided the bactericidal effects required (Bell and Bole, 1976, 1978) while orchard grass required 65 hours of bright sunlight (Bell and Bole, 1978).

High wind velocities were found to carry bacterial aerosols to at least 192 meters (m) from a sprinkler (Sorber et al., 1976). The authors implied that secondary sewage effluent should be chlorinated before sprinkler irrigation.

The fate of certain viruses when applied to the soil has been studied by a number of people. Bitton et al. (1976) found that wastewater acts as a good desorbent of viruses held on soil particles. This phenomenon is believed to be caused by the interaction of organic material in the effluent, the viruses (Bacterial phase T_2 and poliovirus type 1 in this study) and the soil solids. Gilbert et al. (1976) found no human viral pathogens in four wells installed in the groundwater of the alluvial basins of the Flushing Meadows Wastewater Renovation Project near Phoenix, Arizona. On a typical Florida cypress dome, vertical movement of viruses of 3 m and lateral movement of at least 7 m was found. The viruses were also found to survive for at least 28 days in the soil (Wellings et al., 1975). Elliott and Ellis (1977) found that most viruses persist in the

BEGIN LAST LINE OF TEXT HERE
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD. BEGIN SECTIONS HERE

soil for approximately 170 days. Burge and Enkiri (1978) reported that bacteriophage X-174 was adsorbed by four out of five soils in accordance with a Fruendlich isotherm. They also showed that adsorption of viruses was dependent on soil pH, cation exchange capacity, and the ionic strength of the added solution.

Reviews of the biological aspects of land treated with sewage effluent have been presented by Bouwer and Chaney (1974) and Burge and Marsh (1978).

PHYSICAL PARAMETERS

Continuous application of sewage effluent can alter a number of physical properties of the soil. As mentioned earlier, high Na concentrations can produce infiltration problems. Effluents that contain a relatively high load of organic substances could clog soil pores and reduce aeration and infiltration. Drying helps rectify the situation. Also, Jones and Taylor (1965) found that soil clogging under effluent loading occurs three to ten times faster under an anaerobic than an aerobic environment. Consequently, by providing adequate drainage and proper application rates (e.g. those used for efficient crop production), the physical attributes of the soil can be maintained. These parameters are essential in developing treatment designs (Bouwer, 1973).

TREATMENT DESIGNS

Bouwer (1973) has described three systems for soil filtration of conventionally treated sewage. These are:

1. High rate systems with wastewater renovation as the objective.
2. Low rate systems with application rates of 2.5 - 10 cm/week as the goal (e.g. for crop irrigation).
3. Combination of the above with irrigation and renovation as the major objectives.

The following hydrologic factors should be considered in the design for land treatment systems for liquid wastes (Bouwer, 1973):

1. Infiltration rate.
2. Groundwater table fluctuation with infiltration.
3. The effect of system design and management on quality of renovated water.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE

4. The control of underground movement of renovated water below the water table.

The final design of a land disposal treatment system must include design application rates, quality improvement longevity desired, the most appropriate system for application, and the groundwater management below the receiving fields (Bouwer, 1973). The recommended depth of soil through which the effluent should percolate is at least 120 cm of soil (Greenberg and Thomas, 1954). Other precautions concerning pathogens and odors may be needed before a land disposal system can be acceptable to many.

COLLECTION DEVICES

In order to monitor the quality of leachate percolating through the soil, collection devices at different soil depths are needed. The most common type of extractors utilized involve porous ceramic cups or candles (Duke and Haise, 1973; Hansen and Harris, 1975; Harris and Hansen, 1975) and fiber filters (Stevenson, 1978). A number of precautions and calibrations should be completed before the cups are inserted into the soil. Hansen and Harris (1975) have found NO_3-N concentrations with up to $\pm$ 30% variation from the mean in samples that were not pretreated or calibrated. These devices, however, still serve as the most acceptable method for sampling leachate at different soil depths.

MANAGEMENT OF MOUNTAIN MEADOWS

Plant uptake of various trace metals and the quantity and the quality of crops produced by irrigation with secondary sewage effluent is of major concern. Since the sewage effluent was applied to mountain meadow type vegetation, a number of hay quality parameters are of interest.

Mountain meadows in the Rocky Mountain area are commonly harvested as a hay crop. The type of vegetation commonly found in these meadows and on the study site is listed in Table 1.

A number of management procedures can influence the yield and quality of mountain meadow hay. Sprinkler irrigation has been found to be more economical with respect to the amount of water used than flood irrigation (Rouse et al., 1955). Rouse also showed that intermittent irrigation with no applied N encouraged the growth of clover species with a corresponding increase in the protein content of the hay. Miller et al. (1955) also found that P fertilization had no effect on species composition; but, grasses were encouraged by late harvest and N fertilization. The work of Wilhite et al. (1955) indicated that 360 kilograms (kg) of N/hectare (ha) increased the crude protein

BEGIN LAST LINE OF TEXT HERE
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE
8-1/2"
9-1/8"
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

of the hay crop. This N application rate also resulted in elimination of most of the clover. Application rates of 45 to 90 kg of N/ha resulted in decreased protein content of the hay.

Ludwick et al. (1978) found that hay yields and N uptake significantly increased with the addition of up to 269 kg N/ha. The N fertilizer source, however, did not significantly influence yields or the N content of the hay. In another study, Ludwick and Rumberg (1976) found significant yield increases with increasing rates of N and P applications. Campbell and Dotzenko (1975) and Thompson (1976) found that easily determined hay quality parameters could effectively be used to predict the *in vitro* dry matter digestibility of forage samples collected in Colorado.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

SECTION 3

CONCLUSIONS

The field study was used to compare the effects of irrigation of the mountain meadow with sewage effluent vs. ditch water and the presence of natural drainage vs. drainage tiles. The meadow was irrigated for about 20 and 22 weeks in the summers of 1977 and 1978, respectively. The drainage tiles were effective in lowering the groundwater for about 85% of the application season in 1977; but, the groundwater elevations were lowered only about 10% of the season in 1978.

Only the NO_3-N levels in the irrigation sources (prior to application) varied with sampling date in 1977. All other chemical and biological parameters did not significantly change between summer samplings. The sewage effluent contained significantly higher concentrations of most of the chemical and biological constituents than the river water used for irrigation. Only the chloride concentrations in the soil solution, groundwater and tiles in 1978 were increased by the application of sewage effluent. Many of the parameters in the soil water samples from the plots fluctuated with the time of sampling.

In 1977 some of the plant characteristics were significantly affected by the major treatment factors. A higher level of grasses was found in the treatments with drainage tiles. The type of drainage influenced some plant characteristics because of the difference in the characteristics of grasses and legumes and their ability to absorb various nutrients and trace metals. Sewage effluent caused increases in the total uptake of some of the plant nutrients and trace metals. The addition of sewage effluent produced increases in the plant concentrations of Na and Mn. Significantly higher levels of Na and Mn in the effluent as compared to the ditch water, probably caused these increases.

The major treatment factors did not affect the plant distributions measured in 1978. Two plant harvests were made in the summer of 1978, and the time of harvest had a highly significant effect on a number of plant concentrations and/or total uptake values. Proper management of mountain meadows can result in two cuttings with the second harvest providing lower yields than the first cutting (Miller et al., 1955; Rouse et al.,

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.) (4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

1955; Whilhite et al., 1955). The application of sewage effluent resulted in increases in yield and the higher yields resulted in higher amounts of total uptake of some nutrients and metals. Because of the higher Mn levels in the effluent, the addition of sewage effluent resulted in increases in plant Mn concentration. The application of ditch water caused increases in the plant Fe concentrations. The reasons for this effect of the ditch water on the Fe concentrations may have been due to the higher Fe levels in the ditch water.

The time of sampling influenced the levels of the exchangeable cations, total metals, and available micronutrients in the soil samples. The decrease in exchangeable Mg was attributed to the higher levels of Ca as compared to Mg in the irrigation sources. The addition of irrigation water could have accounted for the changes in exchangeable cations. For total metals and micronutrients, changes between samplings could not be totally attributed to additions from the irrigation waters or losses from plant uptake. Consequently, the reason for the changes in these soil properties were not known. The type of drainage was found to influence some of the soil chemical properties for samples from different depths. Since the effect of type of drainage was not consistently reflected in the plant data, the soil differences were not considered important. The application of sewage effluent produced increases in surface soil samples in the exchangeable Na, bicarbonate (HCO_3) extractable inorganic PO_4, and exchangeable K. The higher levels of Na, P, and K in the sewage effluent as compared to the ditch water probably caused the increases in the surface soils.

Results from the field study indicated that the application of sewage effluent at the rate of 7.5 cm/week for two irrigation seasons posed no health or environmental problems. Also, drainage tiles did lower the groundwater levels for about 85% and 10% of the application season in 1977 and 1978, respectively. Leaching of problematic substances into the groundwater or change in the soil properties was found to be of little practical concern. Changes in the level of various N species in the soil were probably the result of using intermittent rather than flood irrigation. Irrigation with effluent resulted in greater plant yields and total uptake of various plant nutrients than were found in plants irrigated with the ditch water. Therefore, application of the effluent resulted in beneficial effects to the hay crop in 1977 and 1978.

It was possible to add 7.5 cm/week of effluent throughout the two winter seasons of this study. This was due to the early snow cover that fell on the plots keeping the soil profile from freezing and thus allowing infiltration into the soil to occur below the snow layer. The time of snowfall is weather dependent and varies from year to year. During years when snow falls and accumulates later, it would be possible to develop an ice sheet

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA 287 (Clin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE
6-1/2"
9-1/8"
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

on the ridges and furrows. This could be done by the use of a plastic sheet, spread on top of the ridges, upon which water would be finely sprayed on the plastic during freezing conditions. A thicker sheet of ice could result that would insulate the soil against freezing until later snowfall would cover the ice and provide more insulation.

Although there were no apparent chemical or biological differences in the parameters measured, due to the two sizes of ridges and furrows, both were generally effective in improving the quality of water before movement into the river. The soil filtration system used in this study for treatment of Hayden, Colorado municipal sewage effluent was effective with the exception of one questionable area. There were relatively high concentrations of some of the indicator organisms that appeared in the soil water at the lower sampling depths during the second year of the study. This aspect should be pursued for further verification.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

SECTION 4

RECOMMENDATIONS

Although this study has given some useful and definitive information, the application of municipal sewage effluent from mountain communities (higher altitudes) to mountain meadows should be investigated under different soil conditions. Other soils may respond differently than those used in this study.

Additionally, a study using an effluent of lesser quality than that of this investigation should be used on mountain meadows under near similar conditions to this study. The effluent used on these plots did not stress the system with the possible exception of the indicator organisms. Further investigations on indicator organism accumulation and movement should be made.

The next step would be summer and winter application of effluent to field scale areas using the methods of this study. It appears that under the proper weather conditions (especially temperature and timely snowfall) as existed at this site during 1977-1978 and 1978-1979, the system could be used successfully.

It must be recognized, however, that it is essential to have an excellent manager and operator of the project so that the activities are timely and properly executed or the project could be a failure.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

SECTION 5

MATERIALS AND METHODS

SUMMER STUDY

Site Description

A mountain meadow situated west of the Hayden, Colorado sewage treatment lagoons was employed for the summer field studies. The land was owned by Mr. Dutch Williams of Hayden. The meadow was situated on a first terrace or bench along the Yampa River and had less than 1% slope. The soil profile consisted of a dark brown silty clay loam to a mottled grey-brown clay. A gravel lens was encountered at a depth of 1.5 to 2.0 m and had tentatively been classified as series unknown, fine montmorillonitic Fluvaguentic Haploboroll. The meadow had been used for hay production for at least ten years and had been flood irrigated during this period.

The water table fluctuated between 60 and 200 cm in the study site. The poor drainage caused the mottled soil colors observed in the soil profile.

Hayden is a town with an elevation of 1977 m, latitude of about 41°N and a population of approximately 1000. Farming, ranching, and coal mining serve as the main industries of the area. Sewage originates from homes and service-oriented businesses within the city limits; therefore, no high concentration of potentially hazardous material appeared to be added to the municipal sewage. Sewage effluent from the Hayden polishing lagoon and ditch water from the Yampa River were used to irrigate the plots.

Experimental Design

Nine 15 m by 15 m plots were constructed for summer studies with the following treatments:

Plot 1: Received 7.5 cm/week application from the polishing pond (SE) and no subsurface drainage was provided.

Plot 2: Received 7.5 cm/week application of ditch water (DW) and no subsurface drainage was provided.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD. BEGIN SECTIONS HERE

Plot 3: Replicate of Plot 2.

Plot 4: Replicate of Plot 1.

Plot 5: Control plot which received no treatment.

Plot 6: Received 7.5 cm/week applications of irrigation ditch water and a subsurface tile line about 75 cm in depth provided drainage.

Plot 7: Replicate of Plot 6.

Plot 8: Received 7.5 cm/week of sewage effluent and a subsurface tile line about 75 cm deep provided drainage.

Plot 9: Replicate of Plot 8.

The general layout of the plots is shown in Figure 1. For statistical purposes, the design was considered as a randomized complete block. Data from plot 5 was not used for the statistical calculations.

The treatment will be labeled as follows for the discussion throughout the report:

SE = plots receiving 7.5 cm/week sewage effluent

DW = plots receiving 7.5 cm/week ditch water

Natural = plots with natural drainage

Tiles = plots with subsurface tiles

Irrigation water and sewage effluent were applied using sprinkler irrigation. Three applications of 2.5 cm/week were applied to each plot. Precipitation amounts during 1977 and 1978 did not drastically alter the irrigation schedule. The plots were irrigated from June 6 to October 7, 1977 and from June 5 to October 20, 1978. The irrigation season, therefore, was five months in 1977 and 5.5 months in 1978.

Water sampling devices were installed at a number of locations in each plot. Porous ceramic cups attached to 1.2 cm polyvinyl chloride tubes were placed at 90, 120, and 150 cm depths in each plot. Wells of 6.2 cm O.D. polyvinyl chloride pipe were positioned in the soil profile to depths of about 180 cm in each plot so that the bottom of each well was below the surface of the groundwater table. Wells of similar dimensions were also installed in each drainage tile. An attempt was made to sample all of these devices in the soil, the ditch water, and sewage effluent for eight times in 1977 and six times in 1978.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

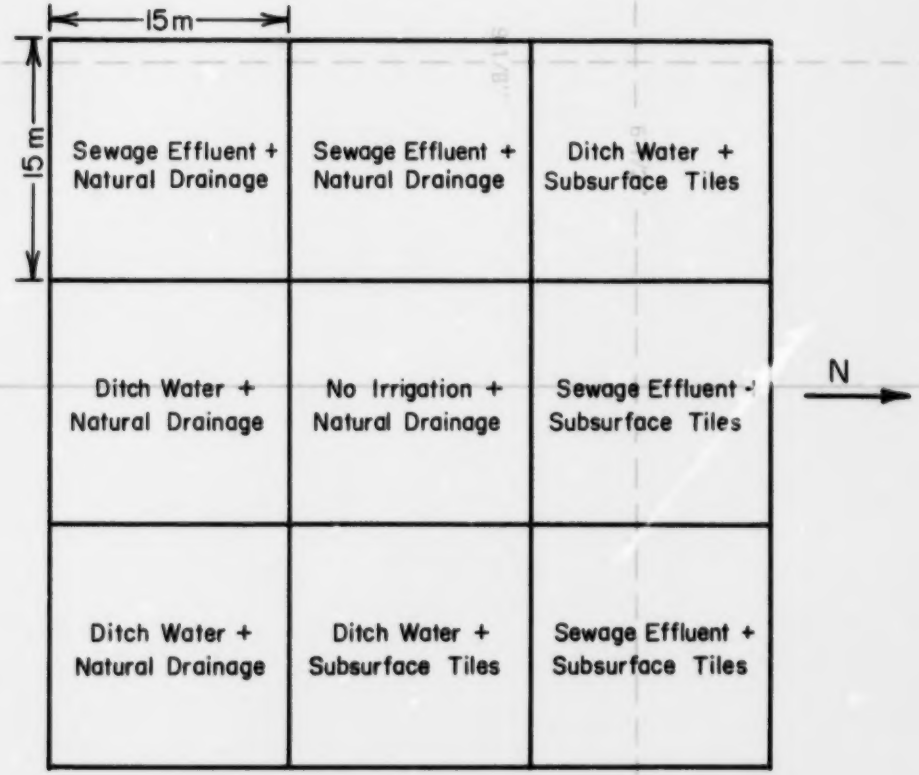

15m
15m
Sewage Effluent + Natural Drainage
Sewage Effluent + Natural Drainage
Ditch Water + Subsurface Tiles
Ditch Water + Natural Drainage
No Irrigation + Natural Drainage
Sewage Effluent + Subsurface Tiles
Ditch Water + Natural Drainage
Ditch Water + Subsurface Tiles
Sewage Effluent + Subsurface Tiles
N

Figure 1. Plot design.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

Piezometers of 1.2 cm O.D. polyvinyl chloride (PVC) tubing were placed to depths of 120, 150, and 180 cm at the north, south, east, and west edge, and the center of the study site. PVC tubes of 1.2 cm O.D. and 150 cm long with holes drilled at 5 cm intervals in the bottom 75 cm, were installed in the center of each plot. The relative elevation of various points in the study area was determined by the Steamboat Springs office of the Soil Conservation Service.

Three soil samples were collected using a 5 cm diameter hydraulic probe. The first sampling was obtained before the treatments were initiated; the second sampling occurred in the spring of 1978; and, the third sampling occurred in the fall of 1978 at the end of the study. In each plot, three soil samples were taken and separated into 0 to 15, 15 to 30, 30 to 60, and 60 to 90 cm depth increments. Soil profile descriptions were completed for three locations within the study site and are presented in Appendix Tables 1 through 5.

Five plant samples were taken from each plot in July, 1977; June, 1978; and August, 1978. A swathe of 75 cm by 180 cm (1.3×10^{-4} ha) was cut using a two-row Jari mower for each plant sample. Each plot sample was weighed on an autopsy balance and then grab subsamples were placed in cloth bags and returned to the laboratory for analyses.

Water Analyses

Analyses of each water sample were generally completed in the order listed below:

1. COD (mg/l)
2. BOD (mg/l)
3. Electrical conductivity (mmhos/cm at 25°C)
4. Cl (ppm)
5. NO_3-N (ppm)
6. NH_4-N (ppm)
7. Ca (ppm)
8. Mg (ppm)
9. K (ppm)
10. Na (ppm)
11. P (ppm)

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE

12. Fecal and total coliform bacteria (count/100 ml)

13. Fecal streptococci (count/100 ml)

Analyses 1, 2, 12, and 13 were completed only on groundwater, drainage tile, sewage effluent, and ditch water samples. Analyses 3-10 were completed on all samples when possible.

A specific ion electrode was utilized to measure Cl. NH_4-N was found by steam distillation, NO_3-N by Cd reduction, and total-N by Kjeldahl determination (American Public Health Association, 1975). A platinum electrode in conjunction with a conductivity bridge was utilized to measure the electrical conductivity (U.S. Salinity Laboratory Staff, 1954). This determination is an indication of the total salt content of the water samples. Atomic absorption spectrophotometry was employed to measure Cd, Zn, Ca, Mg, K, Na, Fe, Mn, Cu, and Ni (Perkin-Elmer, 1971). The Murphy Riley colorimetric procedure was used to find the inorganic P content (American Public Health Association, 1975). COD was determined using the Dichromate reflux method, while BOD was determined after a 5-day incubation period as described by standard methods (American Public Health Association, 1975). M and I Incorporated of Fort Collins analyzed the water samples for BOD, COD, fecal and total coliform, and fecal streptococci. All other determinations were conducted in the laboratories of the Department of Agronomy at Colorado State University.

Piezometer and Groundwater Levels

The depth from the soil surface to the water level in each piezometer and groundwater tube was recorded on a regular basis during summer operation. An arbitary reference level of 200 cm below the surface of the northwest corner of the study site was used to calculate the hydraulic heads at each piezometer and the elevation of the groundwater.

Plant Analyses

To determine the species distribution during the summer study, a 35 cm by 35 cm quadrangle was randomly tossed within a plot. The plants within the quadrangle were then clipped, bagged, and put on ice. This process was completed three times for each plot. The fresh weights of the various plant types were determined and the percentages of the various plant types were computed on a fresh weight basis.

The dry matter yield and percent moisture were calculated for the sample cut with the Jari mower. Plot samples were dried in a forced draft oven at 70°C for 48 hours. The following analyses were completed on each sample:

BEGIN LAST LINE OF TEXT HERE
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

a. Dry matter yield

b. Percent plant moisture

c. Percent crude protein

d. Percent cell contents, percent cell wall contents, percent hemicellulose, percent acid detergent fiber

e. ppm total Cd, Zn, Cu, Ni, Fe, Mn, Mg, Ca, Na, percent total K, and percent total P.

The crude protein content was found by the procedure described by Bremner (1965). NH_4-N and NO_3-N were determined by distillation of potassium chloride (KCl) extracts with sodium hydroxide (NaOH) and Devarda's alloy, respectively (Hanway et al., 1963).

Neutral detergent fiber, hemicellulose, and acid detergent fiber represent parameters used to describe hay quality. Lipids, proteins, and other digestible carbohydrates and water soluble matter comprised the cell contents (van Soest, 1965). Acid detergent fiber included cellulose, lignin, and minerals that the plant material contained (van Soest, 1963).

Separation of these parameters incorporated digestion of the plant material in the presence of various detergents. A neutral detergent (van Soest and Wine, 1967) separated the cell wall constituents, which were only partially available for animal nutrition. An acid detergent (van Soest, 1963) was employed to separate hemicellulose from the acid detergent fiber. Hemicellulose consists primarily of pentoses but also contains other material. Hemicellulose is generally insoluble, but delignification will cause a large portion to become digestible (van Soest, 1969). The digestibility of the acid detergent fiber varies depending upon the amount of lignification.

Total metal contents were determined after the plant samples were digested first in the nitric acid (HNO_3) and then in a perchloric-sulfuric acid mixture.

P was determined colorimetrically using Barton's reagent (Barton, 1948) while all the metals were found using standard atomic absorption techniques (Perkin-Elmer, 1971). The total uptake of various metals and nutrients was found by multiplying plant yields by the concentration.

Soil Analyses

The soils collected during the summer study in the field were air-dried and crushed to pass through a 2-mm sieve. All samples were then analyzed for the constitutents listed below:

BEGIN LAST LINE OF TEXT HERE
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE
6-1/2"
9-1/8"

1. pH of a saturated soil paste was measured by use of a pH meter (Peech, 1965).

2. Electrical conductivity (measure of total salt content) of the extract obtained from the saturated soil paste was found by use of a conductivity bridge and platinum (Pt) electrode (Bouwer and Wilcox, 1965).

3. B content of the saturated extract was analyzed by the colorimetric procedure (John et al., 1975).

4. Using atomic absorption spectrophotometry (Perkin-Elmer, 1971), levels of exchangeable Na, K, Ca, and Mg were determined (Chapman, 1965).

5. Total N was found by block digestion of samples (Tecator, undated) followed by micro-Kjeldahl distillation (Bremner, 1965a).

6. After extraction with KCl, NH_4-N in each soil was found by steam distillation. NO_3-N was determined by distillation on the same extract following the addition of Devarda's alloy (Bremner, 1965b).

7. P was measured by the colorimetric procedure (Watanabe and Olsen, 1965).

8. Zn, Fe, Mn, and Cu were found by atomic absorption procedures (Perkin-Elmer, 1971), after extraction with diethylenetriamine pentaacetic acid (DTPA) (Lindsay and Norvell, 1969, 1978).

9. Upon digestion of each soil with 4 N HNO_3 for five hours at 80°C (Bradford et al., 1975), these soil extracts were analyzed for Ni, Cu, Zn, and Mn using atomic absorption spectrophotometry (Perkin-Elmer, 1971).

Because of the large sample size required for the saturated paste extracts, the 0 to 15 and 15 to 30 cm soils were equally combined for the analyses of exchangeable Na, K, Ca and Mg, pH electrical conductivity (EC), and B content.

Statistics

When a single sample was obtained for plant harvest or species distribution, the analyses of variance (ANOVA) were conducted as shown in Table 2. For the ANOVA involving multiple samplings, a split-plot in time design (Steel and Torrie, 1960) as shown in Table 3 was used.

BEGIN LAST LINE OF TEXT HERE
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

TABLE 2. ANALYSES OF VARIANCE (STEEL AND TORRIE, 1960) FOR DATA WITH A SINGLE SAMPLING.

Source	Degrees of Freedom	Mean sum of squares	F
Main (M)	7	SS(M)/7	MS(M)/MS(Error)
Replication (R)	1	SS(R)	MS(R)/MS(Error)
Water (W)	1	SS(W)	MS(W)/MS(Error)
Drainage (D)	1	SS(D)	MS(D)/MS(Error)
Water x drainage (W x D)	1	SS(W x D)	MS(W x D)/MS(Error)
Error	3	SS(Error)/3	

BEGIN LAST LINE OF TEXT
3/8"
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TABLE 3. ANALYSES OF VARIANCE (STEEL AND TORRIE, 1966) FOR DATA WITH MULTIPLE SAMPLINGS.

Source	Degrees of Freedom	Mean sum of squares	F
Main (M)	7	SS(M)/7	MS(M)/MS(Error a)
Replication (R)	1	SS(R)	MS(R)/MS(Error a)
Water (W)	1	SS(W)	MS(W)/MS(Error a)
Drainage (D)	1	SS(D)	MS(D)/MS(Error a)
Water x Drainage (W x D)	1	SS(W x D)	MS(W x D)/MS(Error a)
Error a	3	SS(Error a)/3	
Samplings (S)	Variable	SS(S)/DF	MS(S)/MS(S x R)
Samplings x Replication (S x R)	Variable	SS(S x R)/DF	

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

In the following discussion, detailed ANOVA tables will not be presented. Rather, significant ($\alpha = 0.05$ level) or highly significant ($\alpha = 0.01$ level) influences will be noted and discussed. Mean values will be given in a table with the information as to the significance of each treatment factor on the parameter.

All statistical calculations were completed using the Statistical Package for Social Sciences (SPSS) available at the Colorado State University Computer Center.

WINTER STUDY

Six ridge and furrow plots (3 m by 15.2 m) were constructed in the late summer of 1977 with raised borders around each plot such that water could be impounded as freezing weather occurred in early winter (see Figures 2, 3, and 4). The purpose of ponding the water was to develop an ice sheet on the top of the ridges such that water could be distributed in the furrows between the soil surface and the ice layer. Three plots had 18 cm ridges and three had 30 cm ridges. In the former three plots, five furrows were made and in the latter only four furrows were formed as shown in Figures 2 and 3. Once an ice sheet of 2.5 to 5 cm was formed and subsequently covered by snow, the plots would be insulated against freezing, thus infiltration and percolation would proceed throughout the winter period.

For the first year a gravity fed irrigation distribution system was built using 5 cm galvanized pipe to bring the effluent from the nearby sewage lagoon to the plots, then a 2.54 cm pipe manifold was connected to the 5 cm pipe to distribute the effluent into each furrow of the plots as illustrated in Figure 4. The valves were adjusted such that the same amount of effluent flow occurred from each outlet of the manifold. The flow rates were adjusted to 11.35 ℓ/minute from each of the four outlets of the manifold and 9 ℓ/minute from each of the five outlets of the manifold. It would require 1.3 hours of effluent flow per week to add 7.6 cm of water to each 3 m by 15.2 m plot. A siphon pump was used to prime the siphon system and to start the flow. A series of valves were designed into the system to allow complete control and flexibility of effluent flow to each or all plots as needed. The head of water was about 120-150 cm which was sufficient for adequate flow rates.

Upon completion of the effluent distribution system and when attempts were made to pond water inside the berm, it became apparent that the infiltration and permability of the soil was so rapid that it was going to be impossible to pond water on the plots long enough to allow the development of an ice sheet as previously planned.

BEGIN LAST LINE OF TEXT HERE
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE
6-1/2"
9-1/8"
BEGIN LAST LINE OF TEXT
3/8"
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

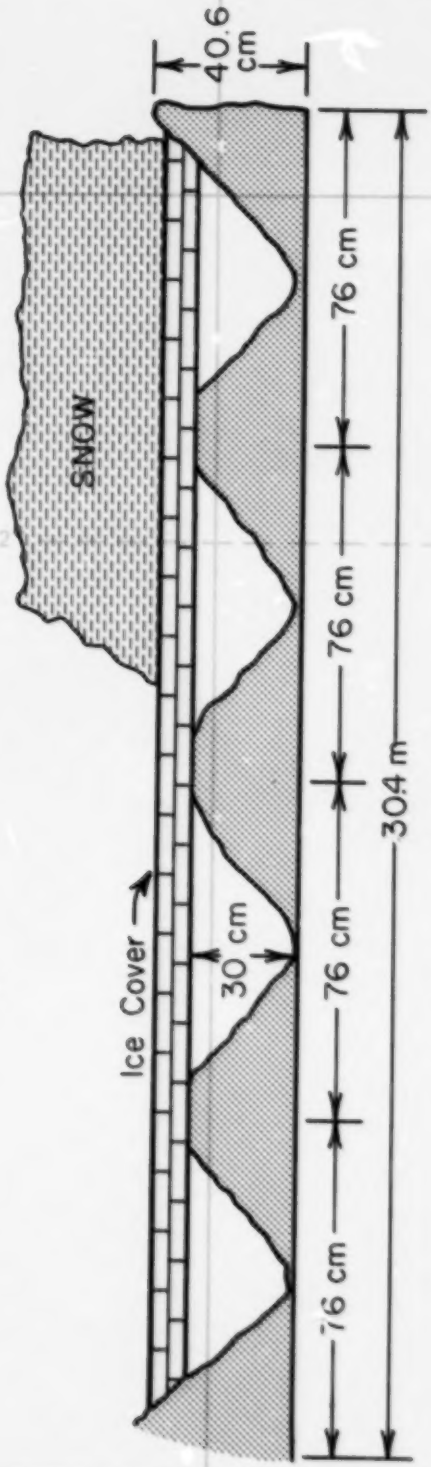


Figure 2. Cross section plot A.

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE
6-1/2"
9-1/8"

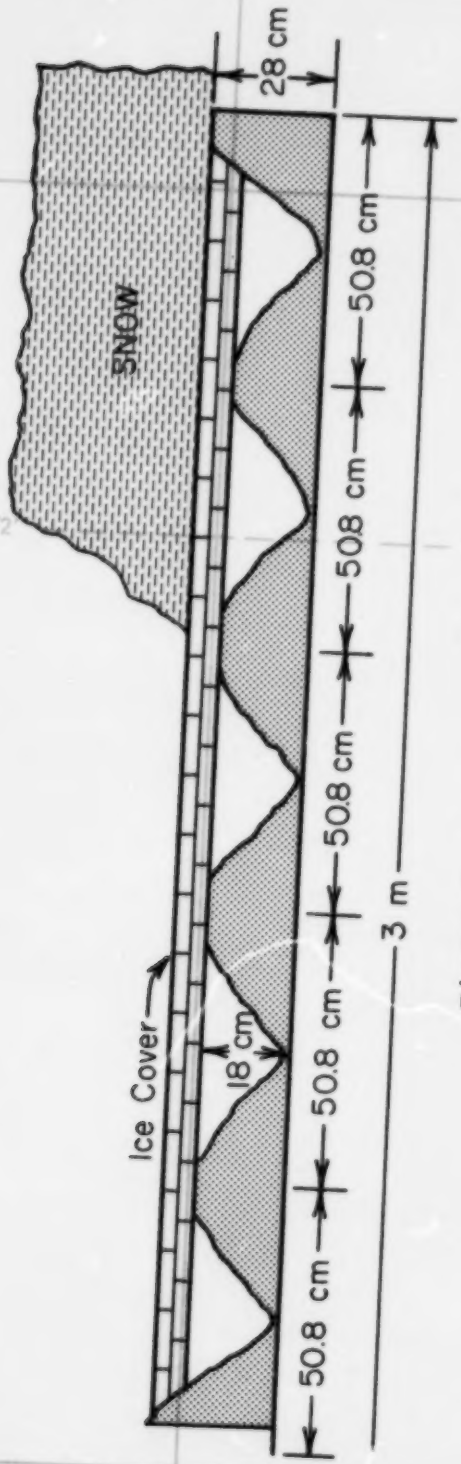


Figure 3. Cross section plot B.

BEGIN LAST LINE OF TEXT
3/8"
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

EPA-287 (Cin.)
(4-76)

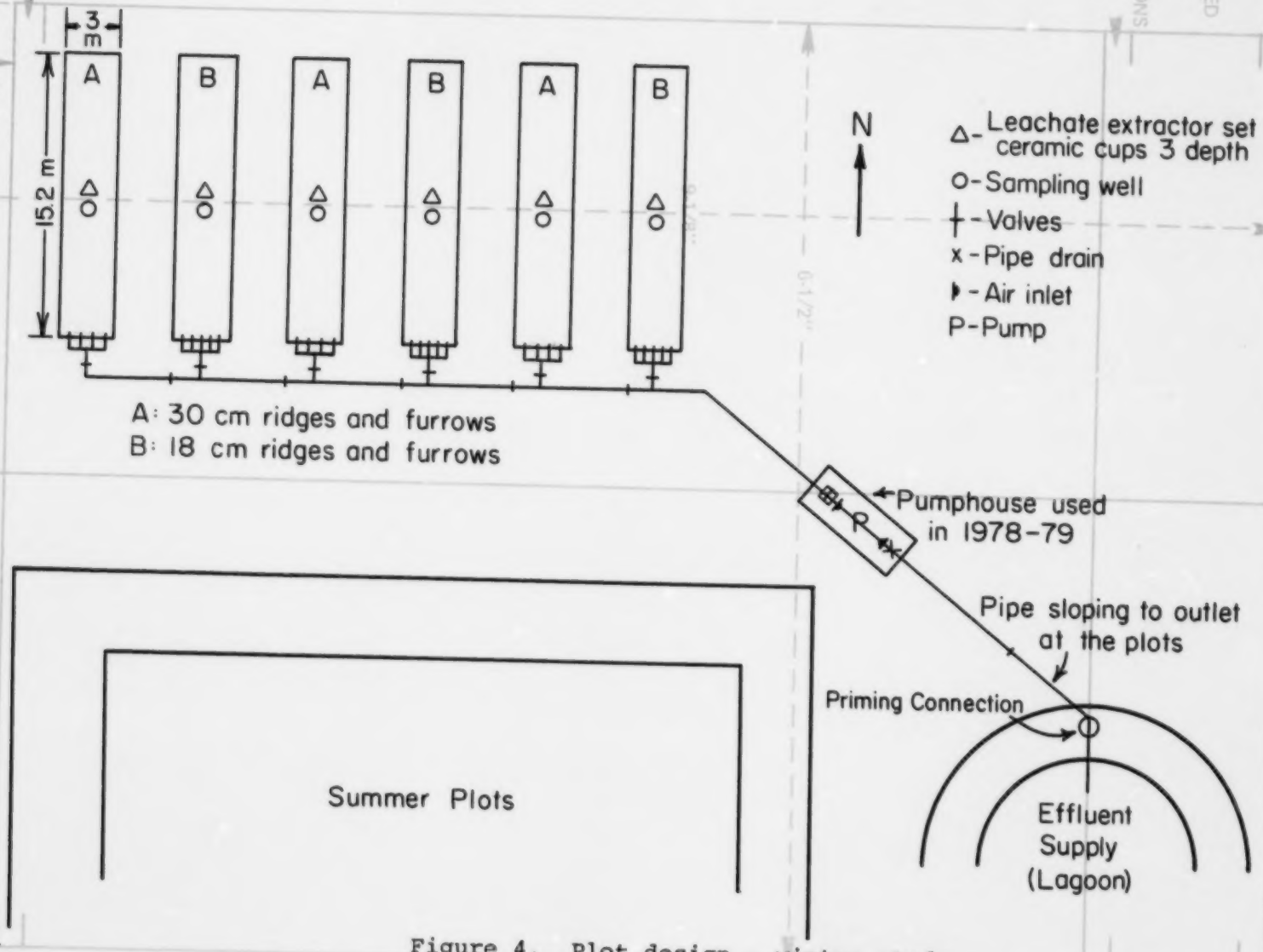


Figure 4. Plot design - winter study.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

The next approach to building an ice sheet was to place a piece of plastic on top of the ridges, then slowly spray a fine mist of water on top of the plastic during subfreezing temperatures. This approach worked but was so slow that it took an inordinate amount of time under rather severe working conditions. During the process of building the ice sheets the snow fell and covered the ice and plastic. Fortunately, the soils were not frozen and infiltration and permeability continued. The effluent was added into the furrows under the snow and flowed under the snow throughout the winter season, the snow being an excellent insulator kept the soil from freezing. Because only one plot could be irrigated at a time using the gravity flow distribution system, an electric pump was installed prior to the second winter season. This effluent supply and distribution system was calibrated prior to use, such that two or three plots could be irrigated simultaneously thus decreasing the total time the system was used each week.

Ceramic cups sealed to 1.27 cm (I.D.) PVC pipe were inserted into the center of each plot at 30, 60, and 90 cm depths and with the top of the PVC pipe extending from the cup to the soil surface. An open well consisting of 1.27 cm (I.D.) PVC pipe was inserted into the soil to a depth of 90 cm. After acid washing with 0.1 N HCl these cups and pipes were inserted into the soil after the removal of a core of soil the same size (I.D.) as the pipe.

Water samples were taken from each cup and from the open well at monthly intervals according to the schedule shown in Tables 19 and 20 for winter operations. A vacuum was placed in the cupped pipes by a vacuum pump for a period of ten to 15 minutes after which the vacuum was maintained overnight before the accumulation fluid inside the cups and pipes was evacuated by a hand pump. These samples were rushed to the laboratory in an ice cooled insulated container, where chemical and biological analyses were made as soon as possible after arrival. In some cases where this was not possible, the samples were kept refrigerated at near 0°C until analyses were made. Chemical analyses for NH_4-N, NO_3-N, total Kjeldahl N, P, Cu, Zn, Fe, Ni, Cd, and Mn were run on all ceramic cup samples that were obtained. Similar chemical analyses along with BOD, COD, fecal streptococcus, fecal coliform, and total coliform numbers were determined on water samples from the wells.

Soil samples were taken from the plots in the fall of 1977, 1978, and in the spring of 1979 from depths of 0 to 15, 15 to 30, 30 to 50, and 60 to 90 cm, three cores were taken from each plot and composited. Some of the soil samples obtained in 1977 were taken from 0 to 30, 30 to 60, and 60 to 90 cm depths instead of the previously described four depths. Soil samples were taken to be able to determine changes in soil chemical properties with depth and time.

BEGIN LAST LINE OF TEXT HERE
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE
6 1/2"
9 1/8"
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

Determinations for NH_4-N, NO_3-N, total Kjeldahl N, $NaHCO_3$ extractable P, HNO_3 extractable Cu, Zn, Ni, Mn, DTPA-extractable Fe, Zn, Cu, and Mn, ammonium acetate (NH_4OAC)-extractable, Na, K, Ca, and Mg, as well as EC and pH were determined from a saturated paste of the soil. The analyses used for the winter study were the same as those referenced in the summer study.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

SECTION 6

RESULTS AND DISCUSSION

SUMMER STUDY

The field study involved comparing the effects of the application of sewage effluent vs. ditch water and the presence of natural drainage or drainage tiles on the properties of the mountain meadow. The levels of various water quality parameters in the two irrigation sources and the levels of the same parameters in water samples from the soil profile, the groundwater and drainage tiles will be presented. Properties of the hay crop in 1977 and 1978 and the characteristics of the three soil samplings will be discussed.

Throughout the discussion of the field results, the use of the terms higher or lower and increase or decrease to describe the effects of a treatment factor will refer to effects that were found to be highly significant ($\alpha = 0.01$) or significant ($\alpha = 0.05$) according to the multiway ANOVA. Multiway ANOVA indicated whether the main treatment factors (type of water, type of drainage or replication), the time of sampling or the interaction terms of the treatment parameters had a highly significant or significant influence on the variable in question. In all tables, the mean values for parameters that received a particular treatment are listed. The significance of the treatment factors at the $\alpha = 0.05$ or 0.01 levels are indicated by * and **, respectively.

Irrigation Sources

The range and average values for the characteristics of the two irrigation sources of 1977 and 1978 are presented in Tables 4 and 5, respectively. One-way ANOVA (Steel and Torrie, 1960) showed that the EC, NH_4-N, Cl, Na, K, Ca, Mg, P, total-N, BOD, COD, and indicator microorganisms were higher in the sewage effluent than in the ditch water in 1977 (Table 4). The effluent contained higher levels of NO_3-N, Cl, Na, K, Ca, Mg, P, total-N, BOD, and COD than the ditch water in 1978 (Table 5). Non-significant differences were found for NO_3-N in 1977 and EC, NH_4-N and indicator organisms in 1978.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

TABLE 4. RANGE AND AVERAGE VALUES FOR CHEMICAL CHARACTERISTICS OF THE TWO IRRIGATION SOURCES IN 1977.

Parameter	Range (Average)						Significant differences
	Sewage effluent (SE)			Ditch water (DW)			
EC (mmhos/cm)	0.51 -	1.37	(0.83)	0.19 -	0.48	(0.33)	**
Cl (ppm)	24.55 -	67.61	(45.25)	1.26 -	53.70	(26.51)	*
NO_3-N (ppm)	0.12 -	3.13	(0.60)	0.11 -	2.49	(0.50)	NS
NH_4-N (ppm)	0.01 -	7.45	(3.97)	0.01 -	1.22	(0.39)	**
Total N (ppm)	2.18 -	7.56	(4.20)	0.53 -	2.33	(1.22)	**
Na (ppm)	51.00 -	184.00	(73.1)	11.0 -	65.00	(31.0)	*
K (ppm)	5.45 -	8.54	(6.97)	0.91 -	7.27	(3.21)	**
Ca (ppm)	28.50 -	61.70	(50.3)	19.00 -	41.80	(28.5)	**
Mg (ppm)	16.50 -	26.80	(23.5)	6.60 -	20.0	(11.1)	**
P (ppm)	1.50 -	4.55	(3.09)	0.01 -	0.36	(0.10)	**
BOD (mg/liter)	2.60 -	20.0	(6.9)	1.20 -	4.00	(2.1)	**
COD (mg/liter)	32.00 -	51.20	(40.5)	16.00 -	57.40	(25.4)	*
Fecal coliform (no./100 ml)	400 -	19,000	(6,300)	20 -	3,000	(570)	**
Total coliform (no./100 ml)	3,800 -	168,000	(56,000)	40 -	51,000	(7,700)	**
Fecal Streptococci (no./100 ml)	10 -	30,000	(4,500)	20 -	3,000	(1,200)	**

NS = non-significant with one-way analysis of variance (ANOVA).
* = significant ($\alpha = 0.05$).
** = highly significant ($\alpha = 0.01$).

TABLE 5. RANGE AND AVERAGE VALUES FOR CHEMICAL CHARACTERISTICS OF THE TWO IRRIGATION SOURCES IN 1978.

Parameter	Range (Average)						Significant differences
	Sewage effluent (SE)			Ditch water (DW)			
EC (mmhos/cm)	0.73 -	1.52	(0.94)	0.20 -	3.12	(0.90)	NS
Cl (ppm)	11.7 -	39.5	(28.7)	6.30 -	10.0	(9.3)	**
NO_3-N (ppm)	0.11 -	0.40	(0.24)	0.05 -	0.18	(0.10)	*
NH_4-N (ppm)	0.10 -	4.16	(1.40)	0.57 -	1.33	(0.98)	NS
Total N (ppm)	3.55 -	5.00	(4.20)	0.63 -	2.28	(1.22)	**
Na (ppm)	49.6 -	66.4	(56.2)	4.9 -	50.0	(21.3)	**
K (ppm)	5.9 -	8.3	(6.8)	0.9 -	3.3	(1.8)	**
Ca (ppm)	55.0 -	115.4	(76.1)	22.4 -	44.2	(32.5)	*
Mg (ppm)	14.0 -	18.9	(17.2)	3.2 -	22.2	(9.8)	*
BOD (mg/liter)	18.0 -	41.0	(26.8)	2.0 -	7.0	(3.6)	**
COD (mg/liter)	43 -	122	(85)	14 -	32	(23)	*
P (ppm)	1.85 -	2.54	(2.22)	0.3 -	0.18	(0.08)	**
Fecal Coliform (no./100 ml)	8,100 -	130,000	(50,000)	180 -	560	(327)	NS
Total Coliform (no./100 ml)	87,000 -	330,000	(199,000)	310 -	4,500	(2,840)	NS
Fecal Streptococci (no./100 ml)	1,300 -	31,000	(11,700)	670 -	1,800	(1,320)	NS

NS = non-significant with one-way analysis of variance (ANOVA).
* = significant ($\alpha = 0.05$).
** = highly significant ($\alpha = 0.01$).

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD. BEGIN SECTIONS HERE

In 1977, only NO_3-N levels fluctuated significantly with the date of sampling. All chemical and biological characteristics in the two water sources did not vary significantly between samplings in 1978. This lack of variation with date indicates that both irrigation sources maintained consistent concentrations of the measured parameters throughout the irrigation seasons.

Trace metal and micronutrient levels were relatively low in the sewage effluent and the ditch water. Concentrations of Cu, Ni, Cd, and Zn were less than five parts per billion (ppb). The effluent contained less than 50 ppb of Fe and from less than 50 to 277 ppb for the ditch water. The sewage effluent contained from 5 to 465 ppb of Mn with a mean of 159 ppb while the ditch water levels varied from less than 5 to 19 ppb with a mean of approximately 11 ppb.

Groundwater, Soil Solution and Tile Samples

Statistical F-tests indicated that most of the chemical constituents did not change significantly among the sampling locations within the soil profile for a given treatment (e.g. samples from porous cups at 90, 120, and 150 cm depth from the groundwater and from the drainage tiles). The EC, Cl, and Mg levels of the well and tile samples were significantly lower in 1978 than those in the samples from the porous cups at 90, 120, and 150 cm depths. The maximum difference between the mean EC, Cl, and Mg concentration of the porous cup samples were 0.20 mmhos/cm, 14 ppm, and 21 ppm, respectively greater than the mean values of the well and tile samples. Also, the NO_3-N level in the porous cup samples at 90 cm depths were significantly higher in 1977 and 1978 than the concentrations found in the samples from all other locations. The mean NO_3-N level for the porous cup samples at the 90 cm depths for all plots and sampling dates was only 1.25 mg/ℓ in 1977 and 1.61 mg/ℓ in 1978. All NO_3-N levels for both years were less than 10 mg/ℓ.

Data from all sampling locations (e.g. porous cups at 90, 120, 150 cm depths of groundwater wells and drainage tiles) and for all dates for a particular plot were grouped together. Missing information prohibited a separate statistical analysis of the data from each sampling location. As stated previously, most of the chemical and biological properties of the water samples were not significantly different among different sampling locations.

The mean values and statistics for each parameter from all sampling locations are presented in Tables 6 and 7. The split-plot in time design was used for completing the multiway ANOVA for the water data from 1977 and 1978.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

TABLE 6. MEAN VALUES AND STATISTICS FOR 1977 FOR CHEMICAL AND BIOLOGICAL DATA FROM ALL SAMPLING LOCATIONS.

		EC	Cl	NO_3-N	NH_4-N	Na
		(mmhos/cm)	(ppm)	(ppm)	(ppm)	(ppm)
Water	SE	0.74	36.8	0.90	0.62	50.6
	DW	0.73	32.9	0.84	0.88	48.0
Drainage	Natural	0.67	33.6	0.86	0.78	51.4
	Tiles	0.80	36.0	0.88	0.71	47.2
Sampling	Date	NS	*	*	*	*

		K	Ca	Mg	PO_4-P	BOD	COD
		(ppm)	(ppm)	(ppm)	(ppm)	(mg/l)	(mg/l)
Water	SE	1.5	46.2	57.9	0.22	2.6	27
	DW	1.8	46.1	57.0	0.22	2.4	19
Drainage	Natural	1.6	46.2	56.1	0.20	2.3	24
	Tiles	1.7	46.2	58.8	0.24	2.7	22
Sampling	Date	*	*	NS	NS	NS	NS

NS = non-significant with one-way analysis of variance (ANOVA).
* = significant ($\alpha = 0.05$)
** - highly significant ($\alpha = 0.01$)

TABLE 7. MEAN VALUES AND STATISTICS FOR 1978 FOR THE CHEMICAL AND BIOLOGICAL DATA FROM ALL SAMPLING LOCATIONS.*

		EC	Cl	NO_3-N	NH_4-N	Total N
		(mmhos/cm)	(ppm)	(ppm)	(ppm)	(ppm)
Water	SE	1.11	31.5**	0.83	3.15	1.43
	DW	1.00	25.0	0.56	2.05	1.50
Drainage	Natural	1.08	28.8	0.84	2.07	1.86
	Tiles	1.02	26.0	0.55	3.12	1.07
Sampling	Date	**	**	*	NS	NS

		Na	K	Ca	Mg	PO_4-P	BOD
		(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(mg/l)
Water	SE	73.8	5.9	72.4	45.8	0.52	6.7
	DW	46.2	3.3	64.7	44.4	0.40	5.1
Drainage	Natural	65.3	4.6	69.1	46.0	0.44	6.4
	Tiles	54.7	4.5	68.0	44.2	0.48	5.4
Sampling	Date	NS	**	**	NS	*	NS

		COD	Fecal coli	Total coli	Fecal strep
		(mg/l)	(no./100 ml)	(no./100 ml)	(no./100 ml)
Water	SE	38	1430	5574	900
	DW	26	1564	2681	700
Drainage	Natural	37	159	4521	702
	Tiles	26	2834	3734	897
Sampling	Date	NS	*	**	**

NS = non-significant with one-way analysis of variance (ANOVA).
* = significant ($\alpha = 0.05$).
** = highly significant ($\alpha = 0.01$).

† Porous cups at 90, 120, and 150 cm depths, groundwater wells, and drainage tiles.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

The ANOVA for the EC of the solutions established that the major treatment factors did not exert a significant effect (Table 6). Relatively low salt levels were found in the samples for all treatments since the mean EC values were all less than 1 mmhos/cm.

The Cl, NO_3-N, NH_4-N, Na, K, and Ca levels fluctuated significantly among water sampling dates. The major treatment factors resulted in non-significant differences in Mg, PO_4-P, BOD, and COD (Table 6).

In 1978, the EC, Cl, NO_3-N, K, Ca, PO_4-P, COD, fecal and total coliform, and fecal streptococci levels in the water samples from the treatment area fluctuated among samplings. The Cl concentrations in the water samples were increased by the addition of sewage effluent since the sewage effluent, before application to the plots, contained about three times as much Cl in solution as did the ditch water (Table 5). The main treatment factors (type of irrigation water and type of drainage) and the time of sampling did not significantly influence the concentrations of NH_4-N, total-N, Na, Mg, or COD of the water samples from the soil profile, groundwater or drainage tiles in the study site (Table 7).

None of the concentrations of the chemical species posed any health or environmental problems. The levels were also within the range for most of the potable groundwaters in the United States (Davis and DeWeist, 1966), although it is not suggested that the leachate is usable for human consumption.

Hydraulic Head and Groundwater Elevation Data

Hydraulic heads were calculated from the measurements that were made in the piezometer tubes. Most of the hydraulic head data obtained from the five sets of piezometers indicate that a horizontal hydraulic gradient exists from all parts of the study site towards the center. In other words, the groundwater was flowing to the plot that received no irrigation water. Figure 3 indicates that water movement occurred from the edges towards the center of the study site and that a vertically upward hydraulic head was observed. Figures 4 and 5 also illustrate that groundwater movement occurred toward the center; however, vertically downward hydraulic heads were found for these two dates.

Because of heavier water application rates surrounding the control plot, the center of the treatment study was essentially a sink for groundwater flow. The irrigated plots received applications of 7.5 cm/week and the meadow area surrounding the study area received relatively heavy flood irrigations. Consequently, the hydraulic head in the piezometers shown in Figures 5 through

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

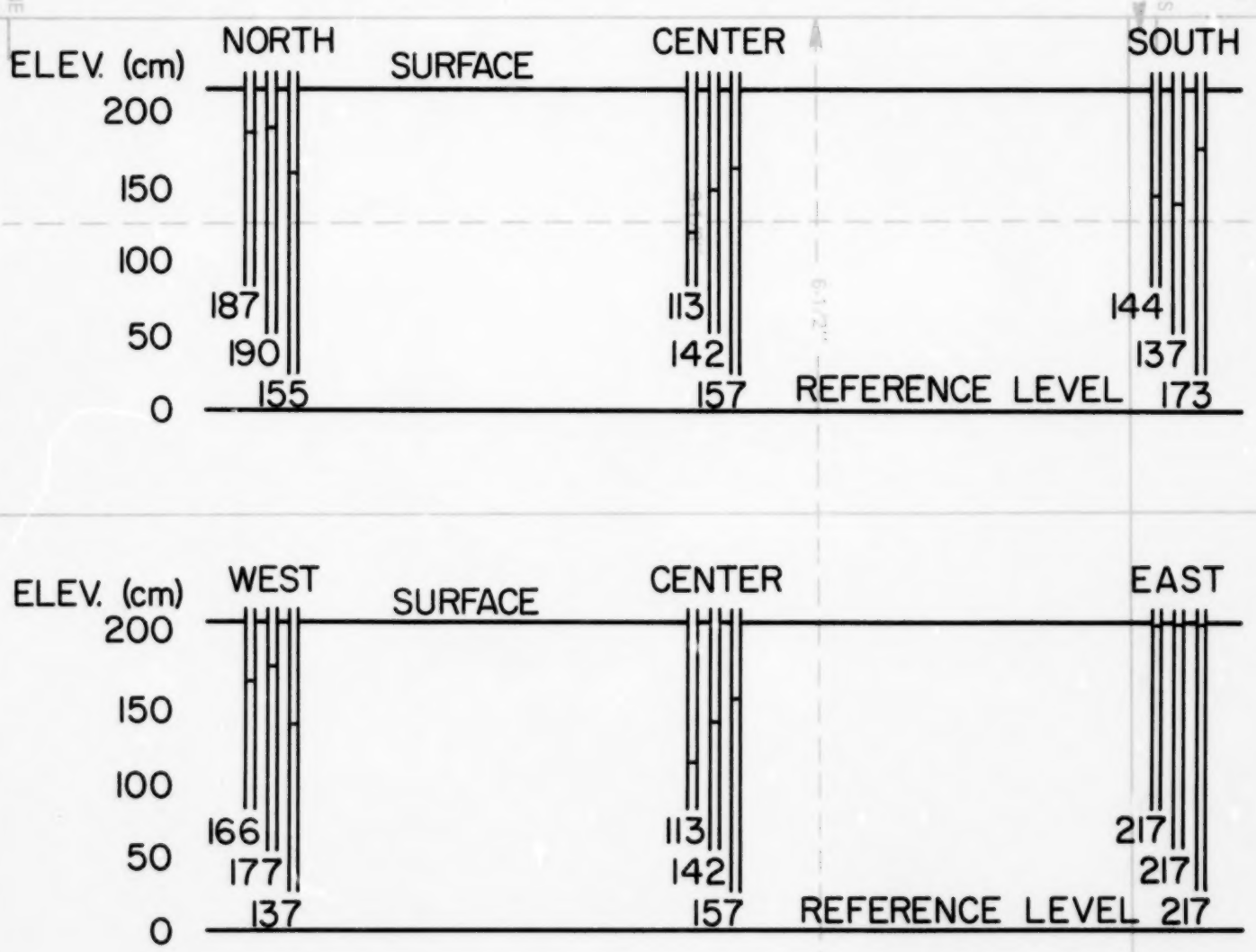


Figure 5. Hydraulic heads in the piezometer tubes for June 9, 1977.

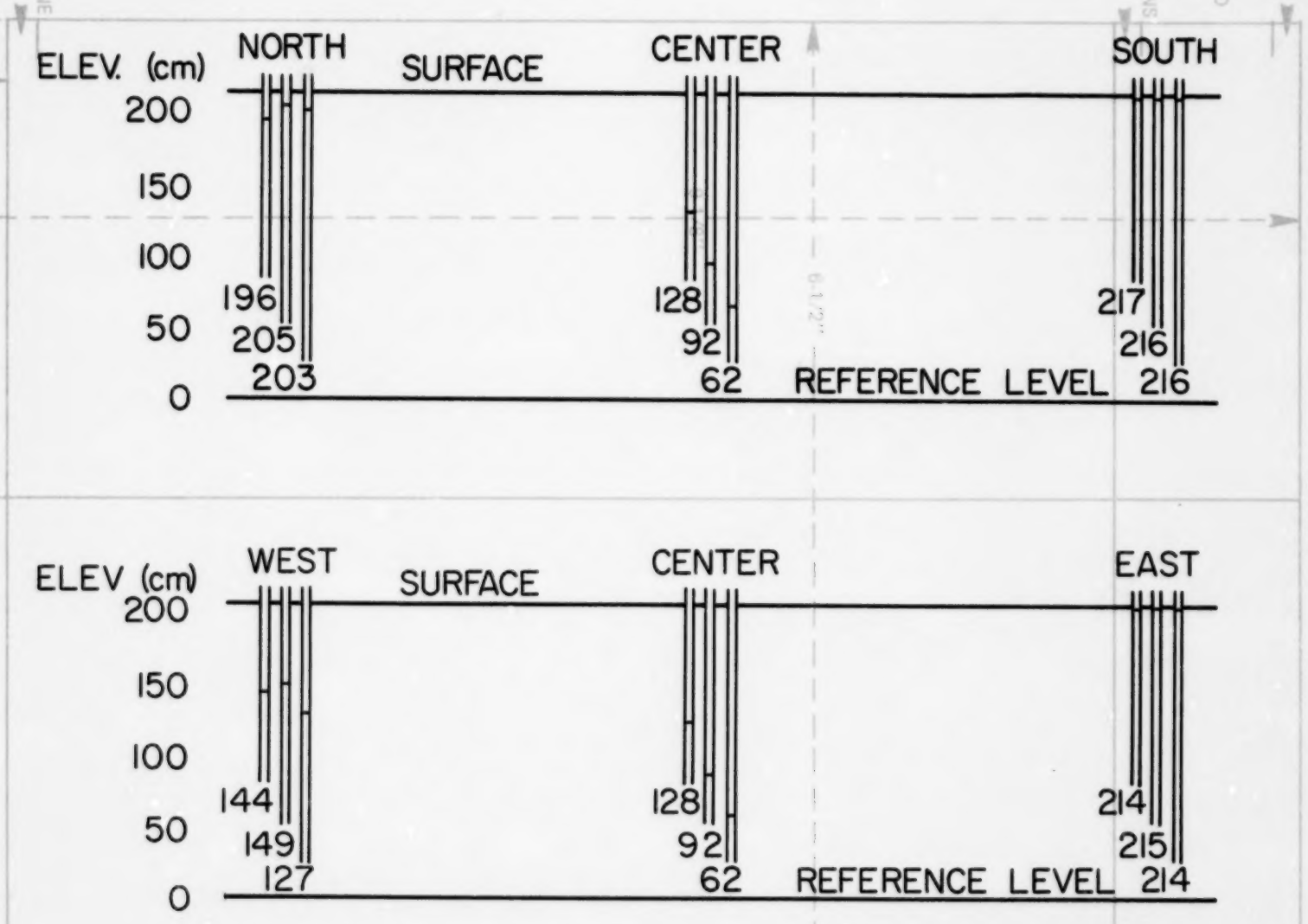


Figure 6. Hydraulic heads in the piezometer tubes for August 24, 1977.

BEGIN LAST LINE OF TEXT
3/8"
PAGE NUMBER
40
EPA-287 (Cin.) (4-76)
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN FIRST LINE OF TEXT HERE
DROPPED HEAD: BEGIN SECTIONS HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA

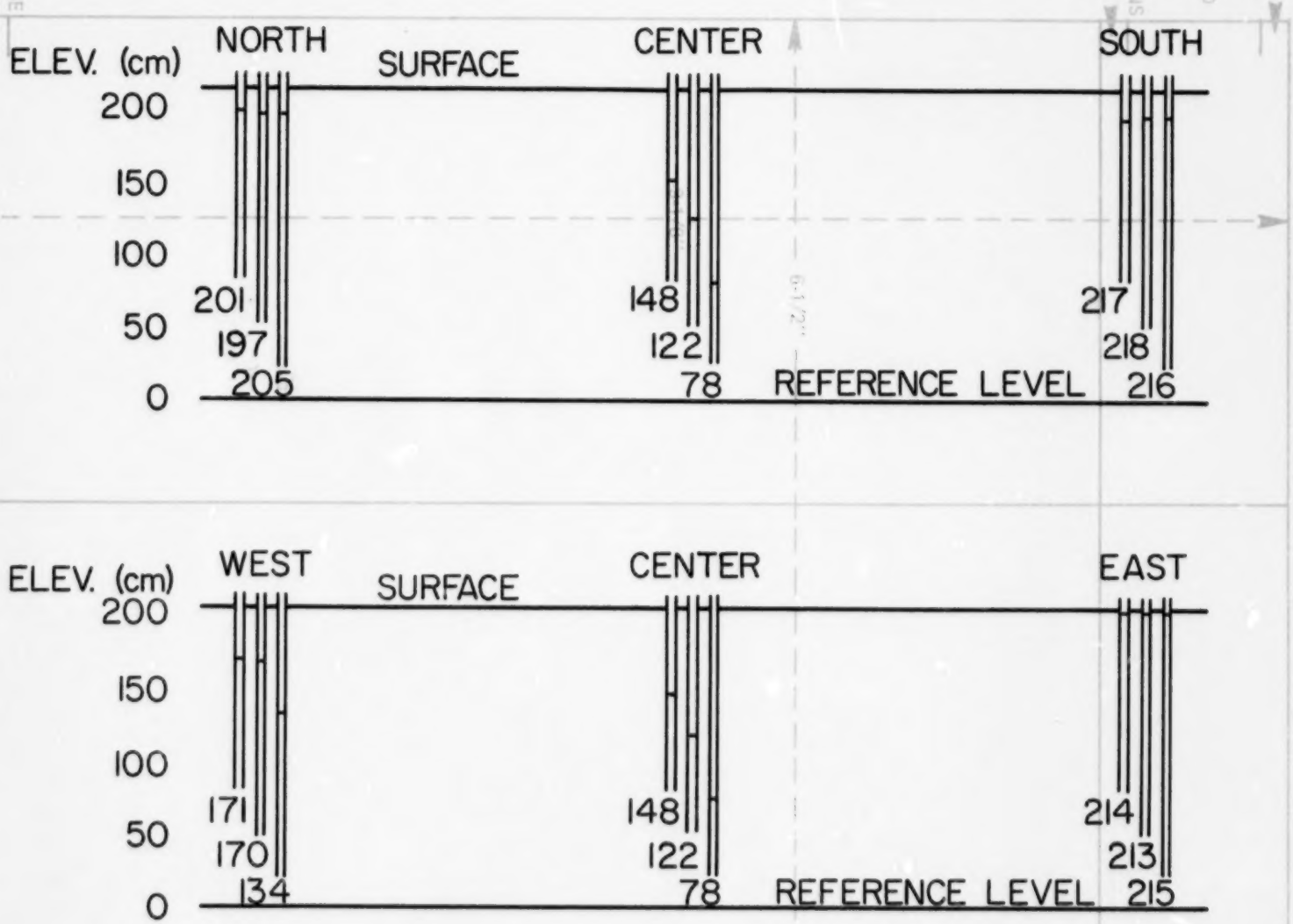


Figure 7. Hydraulic heads in the piezometer tubes for September 19, 1977.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

7 could have resulted from one or more of the following factors:

1. Irrigation treatments within the plots.

2. Irrigation of the meadow area surrounding the study area.

3. Contribution from the irrigation ditch to the east of plots.

4. Contribution from Dry Creek (which had considerable flow throughout the application season) to the east and northeast of the study area.

The detailed hydraulic head data from 1977 and 1978 are presented in the Appendix Tables 4 and 5, respectively.

The groundwater elevations were calculated with respect to the 200 cm reference level. The elevation of the drainage tiles above the reference level were 154, 146, 144, and 142 cm for Plots 6 through 9, respectively.

The groundwater elevations in 1977 showed that the drainage tiles lowered the groundwater at least 5 cm in Plots 6 through 9 relative to Plots 1 through 5 for approximately 85% of the season. Figures 8 through 10 illustrate that groundwater elevations generally sloped towards the drainage tiles. The groundwater elevations for 1977 are presented in Appendix Table 6.

After June 21, 1978, the groundwater elevation was seldom above the level of the drainage tiles in Plots 6 through 9. The tiles lowered the groundwater elevations at least 5 cm in Plots 6 through 9 relative to the groundwater elevations in Plots 1 through 5 for about 10% of the 1978 season. These elevations are presented in Appendix Table 7.

Plant Characteristics for 1977

Multiway ANOVA using the factorial design shown in Table 2 established that type of drainage or irrigation water had no significant effects on the distribution of individual genera or species in 1977. When the data were grouped into "grass" and "legume" categories, the type of drainage exerted a significant effect on the distribution. As discussed previously, the drainage tiles did lower the groundwater elevation for 85% of the 1977 season. This lowering of the groundwater for the treatments with drainage tiles may have encouraged the establishment of grasses.

BEGIN LAST LINE OF TEXT HERE
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

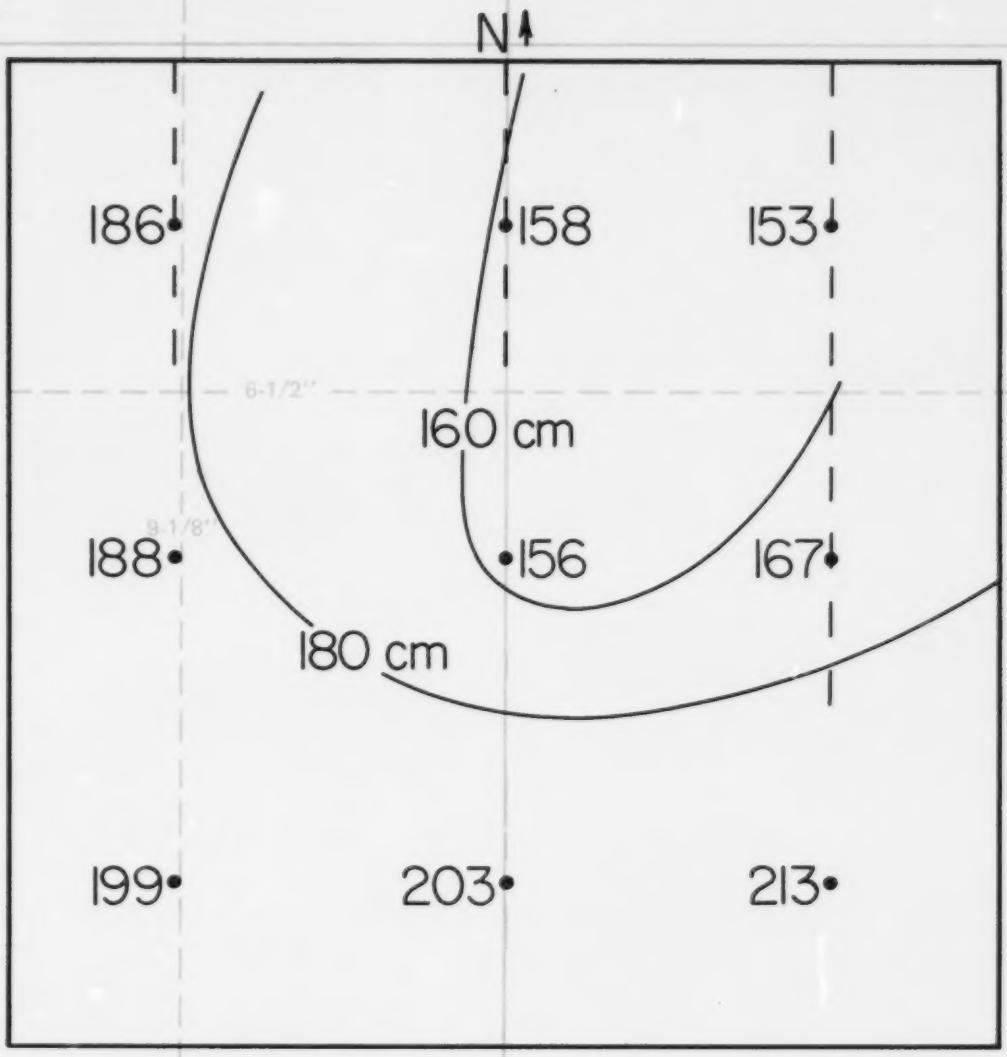


Figure 8. Groundwater elevations (above the reference level) for June 2, 1977.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

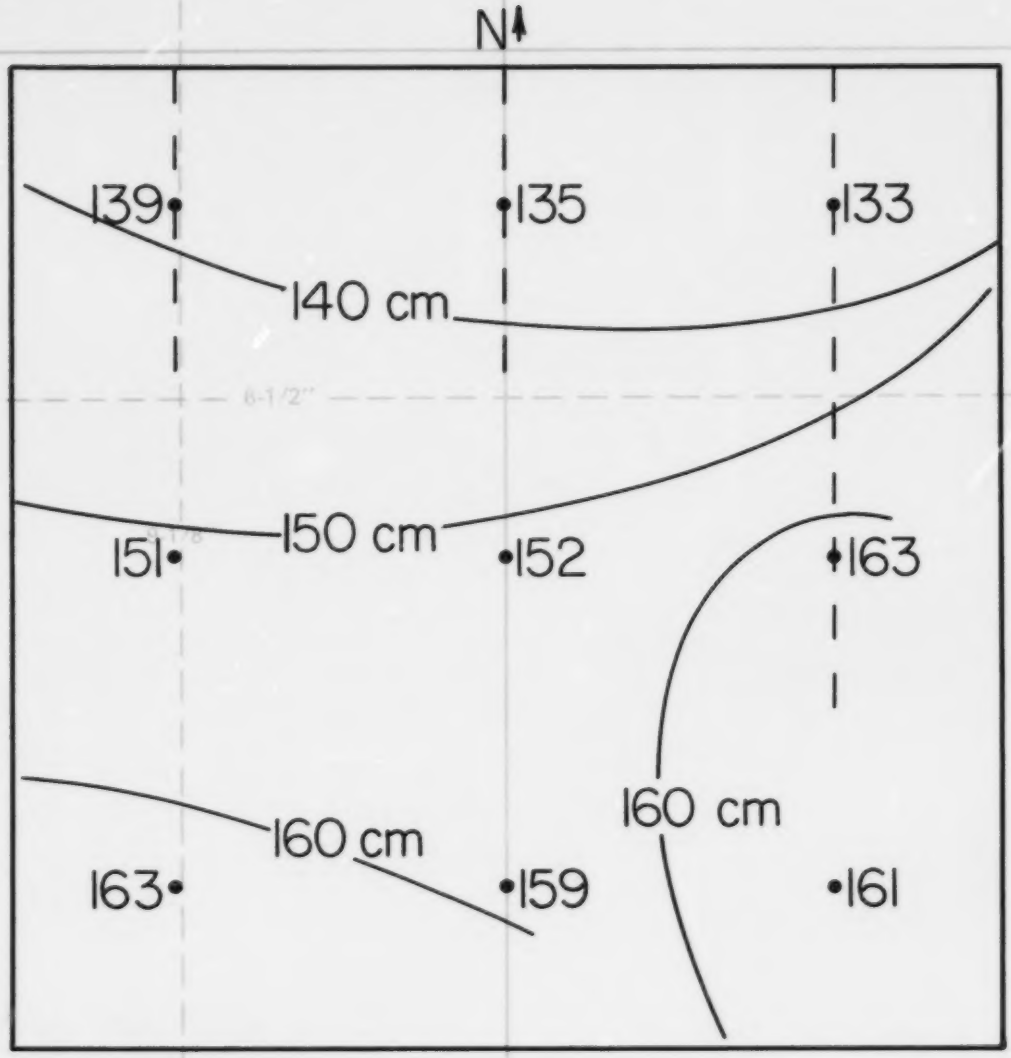


Figure 9. Groundwater elevations (above the reference level) for July 5, 1977.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD. BEGIN SECTIONS HERE

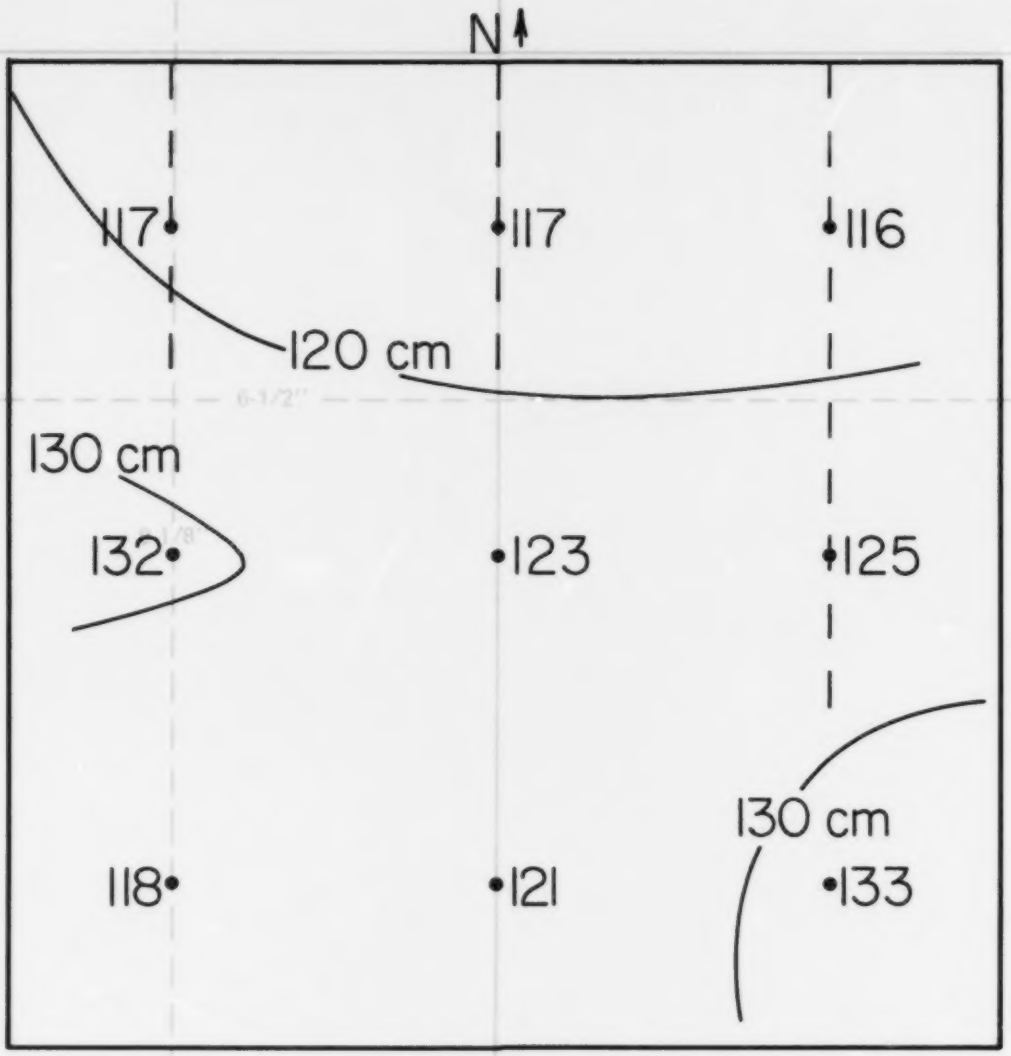


Figure 10. Groundwater elevations (above the reference level) for September 10, 1977.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA. OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

Since only one cutting was made on the plots in 1977, the factorial design shown in Table 2 was used in calculating the ANOVA. The average yield was 5.54 metric tons per ha (mt/ha) (Table 9) and was comparable to similar management systems and nutrient additions as those reported by Rouse et al. (1955) and Miller et al. (1955).

Plants harvested from the treatments with natural drainage contained a higher percent crude protein than did the hay crop taken from treatments with subsurface tiles (Table 9). The higher protein content was due to the larger quantity of legumes on the treatments with natural drainage (Table 8).

The plots which contained subsurface tiles produced a forage crop with a higher percent hemicellulose (Table 9). This contrast can be attributed to the greater quantity of grasses (Table 8) found in the treatments with subsurface tiles.

The yield, moisture content, protein production, NH_4-N, NO_3-N, and neutral and acid detergent fiber were not significantly influenced by the major treatment factors. Also, the NH_4-N and NO_3-N concentrations in the hay pose no problems for livestock consumption (Hanway et al., 1963).

The multiway ANOVA showed that the treatments irrigated with sewage effluent produced a forage crop that contained higher plant concentrations of Na and Mn than the treatments that received ditch water (Table 10). These differences probably resulted from the effluent having approximately twice as much Na and 14 times as much Mn as was measured in the ditch water (table 4). Because of the higher concentrations of Na and Mn in the plants harvested from the plots that received sewage effluent (Table 9), higher total plant uptake of Na and Mn were found in the treatments irrigated with sewage effluent than those irrigated with ditch water (Table 10).

Where natural drainage was used in the study, plants with higher concentration of Na were harvested (Table 10). The difference in Na was due to the higher quantity of legumes in the treatments with natural drainage as compared to those with subsurface tiles (Table 8). Legumes usually contain higher levels of Na (Chapman, 1966). Natural drainage also resulted in greater total uptake by the plants (Table 10) than was measured for treatments with subsurface tiles. The higher total Na uptake was probably the result of the higher plant concentrations of Na.

Where subsurface tiles had been installed, greater total Fe uptake was found (Table 10). Grasses, which were predominant in the plots with subsurface tiles (Table 8), generally contain higher concentrations of Fe than is found in legumes (Chapman, 1966).

BEGIN LAST LINE OF TEXT HERE
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

TABLE 8. PLANT SPECIES DISTRIBUTION FOR 1977.

		Assorted grasses	Red clover	White clover
		%		
Water	SE	19	41	12
	DW	16	28	20
Drainage	Natural	17	39	17
	Tiles	18	29	16

		Dandelions	Sedges	Timothy	Orchardgrass
		%			
Water	SE	12	3	7	3
	DW	10	3	13	3
Drainage	Natural	7	4	7	1
	Tiles	15	2	13	5

		Assorted legumes	Grasses	Legumes
		%		
Water	SE	4	43	57
	DW	7	45	55
Drainage	Natural	9	35	65*
	Tiles	2	54*	46

SE and DW refer to the application of sewage effluent and ditch water, respectively.

* and ** indicate significant differences at the $\alpha = 0.05$ and 0.01 levels, respectively.

TABLE 9. YIELD AND HAY QUALITY PARAMETERS FOR 1977

		Yield	Moisture content	Crude Protein	Protein Production
		mt/ha	- % -	- % -	- - % - -
Water	SE	5.97	79.1	12.6	744
	DW	5.13	79.8	12.6	638
Drainage	Natural	5.43	79.5	13.1*	709
	Tiles	5.66	79.4	12.0	672

		NH_4-N	NO_3-N	Neutral detergent fiber
		- ppm -	- ppm -	- - - - - % - - - - -
Water	SE	140	30	45.4
	DW	138	31	44.5
Drainage	Natural	151	36	43.0
	Tiles	127	24	46.9

		Acid detergent fiber	Hemicellulose
		- - - - - % - - - - -	- - - % - - -
Water	SE	32.4	13.0
	DW	31.6	12.9
Drainage	Natural	31.9	11.1
	Tiles	32.2	14.8**

SE and DW refer to the application of sewage effluent and ditch water, respectively.

* and ** indicate significant differences at the $\alpha = 0.05$ and 0.01 levels, respectively.

TABLE 10. PLANT CONCENTRATIONS AND TOTAL UPTAKE OF NUTRIENTS AND METALS IN 1977

		Na	Na uptake	K	K uptake	Mg	Mg uptake
		- % -	- kg/ha -	- % -	- kg/ha -	- % -	- kg/ha -
Water	SE	0.18**	10.59**	2.22	133	0.14	8.5
	DW	0.09	4.71	2.13	108	0.12	6.4
Drainage	Natural	0.16**	8.78*	2.08	113	0.13	7.4
	Tiles	0.11	6.52	2.27	128	0.13	7.5

		Ca	Ca uptake	Fe	Fe uptake	Mn	Mn uptake
		- % -	- kg/ha -	- ppm -	- kg/ha -	- ppm -	- kg/ha -
Water	SE	0.52	30.8	128	0.78	114*	0.69*
	DW	0.54	27.8	158	0.79	60	0.30
Drainage	Natural	0.56	31.1	128	0.70	86	0.48
	Tiles	0.50	28.6	158	0.86*	89	0.52

		Ni	Ni uptake	Cu	Cu uptake	Zn	Zn uptake
		- ppm -	- kg/ha -	- ppm -	- kg/ha -	- ppm -	- kg/ha -
Water	SE	7.2	0.044	14.6	0.086	21.4	0.128
	DW	7.9	0.041	14.8	0.076	22.2	0.115
Drainage	Natural	7.9	0.044	15.1	0.082	22.2	0.122
	Tiles	7.2	0.041	14.2	0.080	21.4	0.121

(continued)

TABLE 10. (continued)

		Cd	Cd uptake	P	P uptake
		- ppm -	- kg/ha -	- % -	- kg/ha -
Water	SE	0.064	3.8×10^{-4}	0.27	16.1
	DW	0.058	3.0×10^{-4}	0.24	12.2
Drainage	Natural	0.060	3.3×10^{-4}	0.25	13.7
	Tiles	0.063	3.6×10^{-4}	0.26	14.5

SE and DW refer to the application of sewage effluent and ditch water, respectively.

* and ** indicate significant differences at the $\alpha = 0.05$ and 0.01 levels, respectively.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

The major treatment factors did not significantly affect plant concentrations of Na, K, Mg, Ca, Fe, Zn, Ni, Cu, or Cd or the total uptake of K, Mg, Ca, Ni, Cu, Zn, Cd, and P in 1977.

Results for 1978

Using the factorial design (Table 2), the ANOVA indicated that the type of drainage or irrigation water did not significantly influence the amount of each plant species or the quantity of grasses or legumes (Table 14). A t-test (Steel and Torrie, 1960) at the $\alpha = 0.01$ probability level showed that a highly significant increase in the percent grasses was found in 1978 as compared to 1977. These changes may represent seasonal changes, the response of the plant population to the organic-N that may have been mineralized in the soil, or the response of the plants to the groundwater elevations which were generally lower in 1978 than in 1977. Apparently, the grasses were encouraged by the drainage improvement that occurred with the tiles in 1977 and the relatively lower groundwater elevations throughout the study site in 1978.

Two cuttings were made on all plots in 1978. Consequently, the split-plot in time design (Table 3) was used to calculate the ANOVA for the plant data compiled in 1978. Table 14 shows that the addition of sewage effluent caused an increase in yield as compared to the addition of ditch water. The higher yields on the treatments receiving effluent also caused a greater amount of protein production than on the plots receiving ditch water (Table 12).

The plant yields and protein production (Table 12) were higher for the first cutting than for the second harvest. The second cutting essentially represented regrowth of the plants left after the first cutting and the yield was usually smaller than the initial harvest (Rouse et al., 1955).

The major treatment factors or the time of the harvest did not significantly alter the moisture, crude protein, NH_4-N, NO_3-N, neutral and acid detergent fiber or hemicellulose levels (Table 12). Since the distribution of grasses and legumes were relatively constant throughout all the treatment areas in 1978 (Table 11), fewer differences in the hay quality parameters were found in 1978 than were observed in 1977.

The split-plot in time design shown in Table 3 was used for the ANOVA for the plant concentrations and total uptake in 1978.

Because the higher yields of the hay crops from the treatments receiving effluent than those receiving ditch water, higher plant uptake of Na, Mn, and P were found where effluent was the irrigation source (Table 13). The higher Mn level in the effluent as compared to the ditch water (Chapter 5, Irrigation

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

TABLE 11. PLANT SPECIES DISTRIBUTION FOR 1978.

		Assorted grasses	Orchardgrass	Timothy
		- - - - - - - - - - - - - % - - - - - - - - - - - - -		
Water	SE	10	18	22
	DW	9	31	13
Drainage	Natural	9	26	16
	Tiles	10	22	18

		Canadian bluegrass	Red clover	White clover
		- - - - - - - - - - - - - % - - - - - - - - - - - - -		
Water	SE	6	6	7
	DW	6	11	10
Drainage	Natural	5	8	7
	Tiles	7	9	10

		Dandelions	Sedges	Red Fescue
		- - - - - - - - - - - - - % - - - - - - - - - - - - -		
Water	SE	16	3	5
	DW	11	6	3
Drainage	Natural	17	4	4
	Tiles	10	5	4

		Assorted Legumes	Grasses	Legumes
		- - - - - - - - - - - - - % - - - - - - - - - - - - -		
Water	SE	4	79	21
	DW	0	80	20
Drainage	Natural	4	81	19
	Tiles	0	78	22

TABLE 12. YIELD AND HAY QUALITY PARAMETERS FOR 1978.

		Yield	Moisture content	Crude protein	Protein production
		mt/ha	- % -	- % -	- - % - -
Water	SE	4.46**	77.4	12.2	520*
	DW	3.67	78.2	13.3	470
Drainage	Natural	4.08	78.3	13.0	500
	Tiles	4.05	74.3	12.5	490
Cutting	First	5.54**	80.2	11.4	630**
	Second	2.60	75.4	14.1	360

		NH_4-N	NO_3-N	Neutral detergent fiber
		- ppm -	- ppm -	- - - - - % - - - - -
Water	SE	146	91	56.8
	DW	179	116	52.6
Drainage	Natural	140	99	53.6
	Tiles	186	108	55.8
Cutting	First	129	102	59.7
	Second	196	104	49.7

		Acid detergent fiber	Hemicellulose
		- - - - - % - - - - -	- - - % - - -
Water	SE	36.6	20.2
	DW	35.3	17.2
Drainage	Natural	35.4	18.2
	Tiles	36.6	19.2
Cutting	First	37.9	21.8
	Second	34.0	15.6

TABLE 13. PLANT CONCENTRATIONS AND TOTAL UPTAKE OF NUTRIENTS AND METALS IN 1978.

		Na	Na uptake	K	K uptake	Mg	Mg uptake
		- % -	- kg/ha -	- % -	- kg/ha -	- % -	- kg/ha -
Water	SE	0.108	4.6*	2.54	113	0.145	5.6
	DW	0.075	2.3	2.59	112	0.171	5.6
Drainage	Natural	0.092	3.5	2.52	103	0.148	5.6
	Tiles	0.091	3.4	2.61	122	0.168	5.6
Cuttings	First	0.071	4.0	2.62	159**	0.136	6.6
	Second	0.112	2.9	2.51	65	0.180**	4.6

		Ca	Ca uptake	Fe	Fe uptake	Mn	Mn uptake
		- % -	- kg/ha -	- % -	- kg/ha -	- % -	- kg/ha -
Water	SE	0.52	21.0	59	0.26	49*	0.20*
	DW	0.57	19.8	87*	0.32	30	0.11
Drainage	Natural	0.58	22.1	71	0.28	38	0.16
	Tiles	0.50	18.7	75	0.30	40	0.15
Cuttings	First	0.44	24.3**	73	0.39	34	0.19
	Second	0.64**	16.5	73	0.19	44	0.12

(continued)

TABLE 13. (continued)

		Ni	Ni uptake	Cu	Cu uptake	Zn	Zn uptake
		- ppm -	- kg/ha -	- ppm -	- kg/ha -	- ppm -	- kg/ha -
Water	SE	5.2	0.024	9.8	0.042	18.1	0.081
	DW	5.0	0.019	10.1	0.036	19.2	0.071
Drainage	Natural	4.9	0.020	10.0	0.040	18.9	0.077
	Tiles	5.3	0.023	9.9	0.038	18.4	0.075
Cutting	First	5.5	0.030	9.4	0.051**	19.4	0.106**
	Second	4.7	0.013	10.6	0.027	17.9	0.046

		Cd	Cd uptake	P	P uptake
		- ppm -	- kg/ha -	- ppm -	- kg/ha -
Water	SE	0.070	2.8×10^{-4}	0.31	13.0*
	DW	0.075	2.6×10^{-4}	0.30	10.5
Drainage	Natural	0.074	2.9×10^{-4}	0.30	11.6
	Tiles	0.071	2.5×10^{-4}	0.31	11.9
Cutting	First	0.059	3.2×10^{-4}	0.27	14.8
	Second	0.085	2.2×10^{-4}	0.34	8.8

SE and DW refer to the application of sewage effluent and ditch water, respectively.

* and ** indicate significant differences at the $\alpha = 0.05$ and 0.01 levels, respectively.

TABLE 14. SOIL NITROGEN

		NO_3-N (ppm)			
		0 - 15 cm	15 - 30 cm	30 - 60 cm	60 - 90 cm
Water	SE	5.8	2.5	4.8	3.6
	DW	6.8	3.9	3.7	3.1
Drainage	Natural	6.4	3.2	5.1	3.8
	Tiles	6.2	3.3	3.4	2.9
Sampling	1	7.9	2.4	6.1	0.8
	2	6.1	3.7	4.4	5.2
	3	4.9	3.6	2.2	4.1
		NH_4-N (ppm)			
		0 - 15 cm	15 - 30 cm	30 - 60 cm	60 - 90 cm
Water	SE	4.3	4.4	5.3	3.7
	DW	5.3	3.9	3.7	5.7
Drainage	Natural	5.9	5.3	4.4	6.3
	Tiles	3.7	3.0	4.6	3.1
Sampling	1	3.4	1.3	6.3	1.5
	2	7.0	7.4	5.1	9.1
	3	4.0	3.8	2.2	3.4
		Total N (%)			
		0 - 15 cm	15 - 30 cm	30 - 60 cm	60 - 90 cm
Water	SE	0.230	0.156	0.109	0.091
	DW	0.223	0.153	0.119	0.089
Drainage	Natural	0.229	0.160	0.115	0.091
	Tiles	0.224	0.149	0.113	0.089
Sampling	1	0.244b	0.167	0.133	0.094b
	2	0.222a	0.149	0.105	0.089a
	3	0.216a	0.146	0.104	0.087a

SE and DW refer to the application of sewage effluent and ditch water, respectively.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

sources) probably caused the higher plant Mn concentrations in the hay harvested from the treatments irrigated with the sewage effluent (Table 13).

Ditch water produced a crop higher in Fe concentration than was found with the crop irrigated with sewage effluent (Table 13). The reason for this difference may have been due to the higher Fe levels in the ditch water.

Since the yields were higher for the first as compared to the second harvest, the total uptake of K, Ca, Cu, and Zn were higher for the first cutting (Table 13). The plant concentrations of Mg and Ca were higher on the second than the first cutting (Table 13). Possibly, a concentration of Mg and Ca occurred in the regrowth.

The major treatment factors or the time of harvest did not significantly affect the plant concentrations of Na, K, Ni, Cu, Cd, or P or the total uptake of Mg, Fe, Ni, or Cd (Table 13). The type of drainage did not influence plant concentrations or total uptake of Na in 1978 as was found in 1977 because the differences in the distributions of grasses and legumes were less in 1978 than in 1977.

Since detection of changes in soil properties between samplings was desirable, the split-plot in time design shown in Table 3 was used in completing the ANOVA.

Soil N and P

When a multiway ANOVA was completed for all samples at all depths, decrease in total-N from the spring 1977 to the fall 1978 was found in the soil profile (Table 14). The use of intermittent irrigation may have allowed the organic-N that had accumulated after years of flood irrigation to be mineralized.

The major treatment factors or the time of sampling did not significantly influence the levels of NO_3-N and NH_4-N throughout the soil profile (Table 14).

Table 18 was utilized to show that the total-N uptake by the plants harvested in 1977 and 1978 could not be completely attributed to the N in the irrigation sources. Changes in levels of NO_3-N and NH_4-N were not considered since they did not change from the spring of 1977 to the fall of 1978. This table also illustrates that the possible mineralization of organic-N during this period could have influenced the N uptake and growth of the plants.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD. BEGIN SECTIONS HERE

The N input from the irrigation sources (Table 15) was found by using an average of 2.71 mg N/ℓ both years. These values were multiplied by the application rate (7.5 cm/week), the number of weeks of application (20 weeks) and appropriate conversion factors. The result was that irrigation amounted to an average input of 41 kg/ha of N.

Total plant uptake of N was greater than the amount of total N supplied by the irrigation sources (Table 15). The decrease in total N in the soil from 1977 to 1978, however, could have accounted for the N uptake by the plants in all treatment areas. Since crude protein levels in the plants in 1977 and 1978 were not influenced by the type of irrigation (Table 9), the N released from the possible mineralization of soil organic-N could account for the total-N uptake by the plants harvested in the study area. Nitrogen fixation by legumes could also account for some of the total N uptake measured in the study area.

The average decrease in total N in the soil profile (Table 15) was 2067 and 292 kg N/ha for 1977 and 1978, respectively. Duxbury and Peverly (1978) found mineralization of about 850 kg N/ha for the first year in which organic soils in New York were drained for cultivation. This release of N between 1977 and 1978 could have accounted for the N uptake by the plants.

The 0 to 15 cm soils taken from treatments irrigated with sewage effluent had higher levels of HCO_3-extractable inorganic PO_4-P than the soils from plots irrigated with ditch water. This contrast was probably due to the higher levels of inorganic PO_4-P in the effluent as compared to the ditch water (Table 4).

The plots with drainage tiles had a higher level of HCO_3-extractable PO_4-P in the 0- to 15-cm samples than in the plots with natural drainage. Also, the PO_4-P levels were higher in the first soil sampling in the 15 to 30 and 60 to 90 cm depths The reason for the differences attributed to the type of drainage may have been caused by the differences in groundwater elevations that were observed between treatments that contained natural drainage vs. those that contained drainage tiles.

Salts, pH, and Exchangesable Cations

The ANOVA based on the split-plot in time design showed that the addition of sewage effluent increased the exchangeable Na and K in the 0 to 30 cm soils over the levels found in the plots receiving ditch water (Table 20). In 1977 and 1978, the effluent had more than twice the amount of Na and three times the quantity of K than in the ditch water (Tables 4 and 5).

BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
3/8"

EPA-2C7 (Cin.)
(4-76)

TABLE 15. SOIL CHANGES IN TOTAL N, ADDITIONS FROM IRRIGATION AND TOTAL PLANT UPTAKE FOR 1977 AND 1978 †

Means for all samples - 1977

0 - 15 cm $\frac{(0.244-0.222)\text{g N}}{100\text{g soil}} \times 15\text{ cm} \times \frac{10\text{ cm}}{\text{ha}} \times \frac{1.3\text{g}}{\text{cm}} \times \frac{1\text{ kg}}{10\text{ g}} = \frac{429\text{kg N}}{\text{ha}}$

15 - 30 cm $\frac{(0.167-0.149)\text{g N}}{100\text{g soil}} \times 15\text{ cm} \times \frac{10\text{ cm}}{\text{ha}} \times \frac{1.3\text{g}}{\text{cm}} \times \frac{1\text{ kg}}{10\text{ g}} = \frac{351\text{kg N}}{\text{ha}}$

30 - 60 cm $\frac{(0.133-0.105)\text{g N}}{100\text{g soil}} \times 15\text{ cm} \times \frac{10\text{ cm}}{\text{ha}} \times \frac{1.3\text{g}}{\text{cm}} \times \frac{1\text{ kg}}{10\text{ g}} = \frac{1092\text{kg N}}{\text{ha}}$

60 - 90 cm $\frac{(0.094-0.089)\text{g N}}{100\text{g soil}} \times 15\text{ cm} \times \frac{10\text{ cm}}{\text{ha}} \times \frac{1.3\text{g}}{\text{cm}} \times \frac{1\text{ kg}}{10\text{ g}} = \frac{195\text{kg N}}{\text{ha}}$

Total soil change = (429 + 351 + 1092 + 195)kg/ha = 2067kg N/ha

N added by irrigation† = 41kg N/ha

Plant uptake of N in 1977 = 111kg N/ha

Means for all samples - 1978

0 - 15 cm $\frac{(0.222-0.216)\text{g N}}{100\text{g soil}} \times 15\text{ cm} \times \frac{10\text{ cm}}{\text{ha}} \times \frac{1.3\text{g}}{\text{cm}} \times \frac{1\text{ kg}}{10\text{ g}} = \frac{117\text{kg N}}{\text{ha}}$

15 - 30 cm $\frac{(0.149-0.146)\text{g N}}{100\text{g soil}} \times 15\text{ cm} \times \frac{10\text{ cm}}{\text{ha}} \times \frac{1.3\text{g}}{\text{cm}} \times \frac{1\text{ kg}}{10\text{ g}} = \frac{59\text{kg N}}{\text{ha}}$

30 - 60 cm $\frac{(0.105-0.104)\text{g N}}{100\text{g soil}} \times 15\text{ cm} \times \frac{10\text{ cm}}{\text{ha}} \times \frac{1.3\text{g}}{\text{cm}} \times \frac{1\text{ kg}}{10\text{ g}} = \frac{39\text{kg N}}{\text{ha}}$

60 - 90 cm $\frac{(0.089-0.087)\text{g N}}{100\text{g soil}} \times 15\text{ cm} \times \frac{10\text{ cm}}{\text{ha}} \times \frac{1.3\text{g}}{\text{cm}} \times \frac{1\text{ kg}}{10\text{ g}} = \frac{78\text{kg N}}{\text{ha}}$

Total soil change = (117 + 58 + 39 + 78)kg N/ha = 292kg N/ha

N added by irrigation† = 41kg N/ha

Plant uptake of N in 1978 = 160kg N/ha

† These values represent the mean of the N added from the sewage effluent and the ditch water.

The exchangeable Na and Ca in the 0 to 30 cm soils, the exchangeable K in the 30 to 60 and 60 to 90 cm soils, and the exchangeable Mg at all depths varied significantly between the three soil samplings. Only the exchangeable Mg decreased consistently between samplings (Table 17). The Ca levels in both types of irrigation water were greater than the levels of Mg (Tables 4 and 5). Since Ca is held more strongly on cation exchange sites, Mg was probably replaced by Ca that originated in the irrigation sources.

The salt levels for the 60 to 90 cm soils and the pH at all depths consistently increased between samplings. The reason for the changes in salts for the 60 to 90 cm soils is unknown.

The pH of the saturated pastes from all soil depths indicated that the soils were slightly calcareous (Table 17). The exchangeable Mg levels consistently decreased for the three soil samples (Table 17) and the solution levels of Mg also decreased concommittantly with the exchangeable Mg. Assuming that the partial pressure of carbon dioxide (CO_2) in the saturated pastes was similar for all samples, the decrease in Mg may be attributed to the precipitation of Mg as a slightly soluble mixture of Ca and Mg carbonate (Hassett and Jurinak, 1971). The decrease of Mg in solution would result in a higher pH in the saturated pastes.

Trace Metals and Micronutrients

The levels of the trace metals and micronutrients in the 4 N HNO_3 extracts of the soil (heated to 80°C for four hours) will be referred to as total concentrations in the subsequent discussion. The DTPA-extractable levels of Zn, Cu, Mn, and Fe from soil samples have been correlated to the availability of these micronutrients for plant growth (Lindsay and Norvell, 1978).

The 0 to 15 cm soils from plots in which sewage effluent was applied contained higher levels of total Zn and DTPA-Cu than soils from plots in which ditch water was used (Table 18). The reason for this difference is unknown since both irrigation sources contained low levels of Zn.

Soils from plots that were naturally drained were found to have higher levels of DTPA-Mn at 15 to 90 cm, and total Zn at 0 to 15 cm than the soils from the treatments with drainage tiles. The effect of the drainage tiles in lowering the groundwater elevations in 1977 may have caused these differences. The soil differences in DTPA-Mn attributed to natural drainage had no apparent effect on the Mn concentrations or total Mn uptake in the plants (Table 10).

TABLE 16. SOIL BICARBONATE-EXTRACTABLE PHOSPHATES

		PO_4-P (µg/g)			
		0 - 15 cm	15 - 30 cm	30 - 60 cm	60 - 90 cm
Water	SE	35.0**	22.7	20.6	17.3
	DW	22.2	18.6	21.7	18.6
Drainage	Natural	28.1	17.1	22.6	15.0
	Tiles	32.8*	24.2	20.4	21.0
Sampling	1	39.6	28.2b	30.7	28.7b
	2	27.5	17.6a	14.1	11.5a
	3	24.2	16.1a	19.7	14.0a

SE and DW refer to the application of sewage effluent and ditch water, respectively.

* and ** indicate significant differences at the $\alpha = 0.05$ and 0.01 levels, respectively.

TABLE 17. SALTS, pH, AND EXCHANGEABLE CATIONS IN THE SOIL SAMPLES.

		Ex. Na (me/100 g)			Ex. K (me/100 g)		
		0 - 30 cm‡	30 - 60 cm‡	60 - 90 cm	0 - 30 cm	30 - 60 cm	60 - 90 cm
Water	SE§	0.45**#	0.40	0.38	0.94*#	0.60	0.49
	DW§	0.36	0.35	0.33	0.81	0.63	0.49
Drainage	Natural	0.39	0.36	0.35	0.87	0.62	0.49
	Tiles	0.42	0.39	0.36	0.88	0.61	0.49
Sampling	1	0.45b†	0.40	0.39	0.99	0.74b	0.56c
	2	0.31a	0.31	0.30	0.80	0.53a	0.43a
	3	0.47b	0.40	0.37	0.82	0.57a	0.49a

		Ex. Ca (me/100 g)			Ex. Mg (me/100 g)		
		0 - 30 cm	30 - 60 cm	60 - 90 cm	0 - 30 cm	30 - 60 cm	60 - 90 cm
Water	SE	17.82	21.05	24.58	5.08	5.38	7.52
	DW	18.38	21.51	24.10	4.85	5.18	6.88
Drainage	Natural	17.90	20.08	24.18	4.95	5.01	6.85
	Tiles	18.30	22.48	24.50	4.98	5.55	7.55
Sampling	1	17.02a	20.04	23.33	6.33c	6.52a	8.61b
	2	19.84b	21.14	24.32	4.45b	4.95b	7.01a
	3	17.46a	22.60	25.38	4.13a	4.40a	5.97a

(continued)

TABLE 17. (continued)

		EC (µg/g)			pH		
		0 - 30 cm	30 - 60 cm	60 - 90 cm ‡‡	0 - 30 cm	30 - 60 cm	60 - 90 cm
Water	SE	311	240	192	7.2	7.4	7.6
	DW	306	211	178	7.2	7.4	7.6
Drainage	Natural	305	240	190	7.2	7.4	7.5
	Tiles	312	211	180	7.2	7.4	7.7
Sampling	1	330	192	148a	7.0a	7.3a	7.4a
	2	286	241	196b	7.2b	7.4a	7.6b
	3	308	246	212b	7.4c	7.5b	7.7c

† Values followed by the same letter are not significantly different at the α = 0.05 level according to Duncan's Multiple Range Test.

‡‡ Significant interactions were found for S x D for exchangeable Na at 0 to 30 and 30 to 60 cm, and S x W for exchangeable Na at 30 to 60 and salts at 60 to 90 cm.

§ SE and DW refer to the application of sewage effluent and ditch water, respectively.

* and ** indicate significant differences at the α = 0.05 and 0.01 levels, respectively.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

For the three soil samples taken in the spring, 1977 to the fall, 1978, statistical differences were observed among sampling in the total Cu at all depths, total Mn at 0 to 15 cm, total Ni at all depths, total Zn at 0 to 15 cm, DTPA-Cu at 0 to 15 cm and 30 to 60 cm, DTPA-Zn at 0 to 15 cm and 60 to 90 cm, DTPA-Mn at 15 to 30 cm and 30 to 60 cm, and DTPA-Fe at 30 to 60 cm (Table 18). The reason for these changes are unknown, since consistent increases or decreases for the three soil samplings were not observed in the soil constituents mentioned above (Table 18).

None of the major treatment factors or the time of sampling had a significant effect on the B levels in the saturated paste extracts (Table 18).

WINTER STUDY

Chemical Analyses of Soils (Table 19)

Ammonium Nitrogen --

The NH_4 content of the soil in the top 30 cm and the 60 to 90 cm depth of soil increased from 1977 to 1979. Such was not true of the 30 to 60 cm depth. Generally the increases in NH_4-N content of the 0 to 15 cm depth may have been due to organic matter decomposing and N mineralization. However, these NH_4-N contents of the soil profile were not large nor would they be considered a problem for any plant growth. In fact for optimum plant growth, additional N would have to be added.

Total Nitrogen --

Statistically, the total-N content of the soil profile in 1978 was less than that in 1977 when the study started. There was a significant increase in total-N in the middle two depths in 1979 over that of 1978. There were no differences measured between 1977 and 1979 except at the 0 to 15 cm depth. If the 1979 total-N data had been less than the 1978 data, the pattern would have been similar to the summer study. Such was not the case however. The reasons for the differences in the total-N changes in the summer and winter study was not readily apparent. One possible explanation is that the winter study plots were not irrigated during the summer and the dryness may have prevented rapid mineralization as was apparently true of the summer plots. This did not account for the statistically significant decrease from 1977 to 1978.

As was expected, the total-N pattern with depth was normal since it roughly paralleled the organic matter distribution of the soil profile

Nitrate Nitrogen --

There was a general increase in NO_3-N content from 1977 to 1979. There were statistically significant differences in NO_3-N

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

TABLE 18. MICRONUTRIENTS AND TRACE METALS IN THE SOIL SAMPLE.

		Total Cu (µg/g)			
		0 - 15 cm	15 - 30 cm	30 - 60 cm	60 - 90 cm
Water	SE[#]	21.0	20.2	18.4	18.7
	DW	20.7	20.0	18.5	18.8
Drainage	Natural	21.0	21.0	18.9	19.0
	Tiles	20.7	19.2	18.0	18.5
Sampling	1	23.4b[†]	23.3b	22.5b	22.2b
	2	19.2a	18.2a	16.1a	16.5a
	3	20.0a	18.8a	16.7a	17.4a
		Total Mn (µg/g)			
		0 - 15 cm	15 - 30 cm	30 - 60 cm	60 - 90 cm
Water	SE	303	269	257	319
	DW	298	293	275	296
Drainage	Natural	305	305	301	324
	Tiles	296	257	232	291
Sampling	1	314b	303	279	322
	2	287a	282	255	304
	3	300ab	259	264	296
		Total Ni (µg/g)[‡]			
		0 - 15 cm	15 - 30 cm	30 - 60 cm	60 - 90 cm
Water	SE	25.3	22.8	21.7	23.5
	DW	24.7	22.8	22.5	23.1
Drainage	Natural	24.7	23.5	22.3	23.5
	Tiles	25.3	22.1	21.9	23.1
Sampling	1	25.8b	24.5b	23.1b	23.9b
	2	29.0c	27.1c	27.4c	29.2c
	3	20.2a	16.8a	16.4a	16.8a

(continued)

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-237 (Cle.)
(4-76)

TABLE 18. (continued)

		Total Zn (µg/g)			
		0 - 15 cm	15 - 30 cm	30 - 60 cm	60 - 90 cm
Water	SE	75.3** ++	70.8	59.7	61.6
	DW	72.5	72.9	63.1	61.6
Drainage	Natural	75.2**	75.6	61.8	61.7
	Tiles	72.6	68.1	61.0	61.5
Sampling	1	67.8a	66.9	58.6	56.3
	2	73.0b	70.5	62.4	62.2
	3	81.0c	78.3	63.3	66.4

		DTPA Cu (µg/g)			
		0 - 15 cm	15 - 30 cm	30 - 60 cm	60 - 90 cm
Water	SE	2.5	2.5	2.6	2.8
	DW	2.4	2.5	2.4	2.8
Drainage	Natural	2.6	2.6	2.5	2.7
	Tiles	2.3	2.4	2.5	2.9
Sampling	1	2.4ab	2.3	2.3a	2.7
	2	2.3a	2.5	2.4a	2.8
	3	2.6b	2.7	2.7b	3.0

		DTPA Zn (µg/g)			
		0 - 15 cm	15 - 30 cm	30 - 60 cm	60 - 90 cm
Water	SE	2.5	1.9	1.3	1.2
	DW	2.4	1.6	1.3	1.3
Drainage	Natural	2.5	1.9	1.3	1.2
	Tiles	2.4	1.6	1.3	1.3
Sampling	1	2.7b	1.7	1.3	1.2b
	2	2.0a	1.4	0.9	0.9a
	3	2.7b	2.2	1.6	1.6c

(continued)

TABLE 18. (continued)

		DTPA Mn (µg/g)[§]			
		0 - 15 cm	15 - 30 cm	30 - 60 cm	60 - 90 cm
Water	SE	32	18	16	15
	DW	26	17	20	18
Drainage	Natural	32	20*	22*	19*
	Tiles	26	15	14	14
Sampling	1	33	17a	13a	14
	2	36	21b	22b	18
	3	19	15a	18b	17

		DTPA Fe (µg/g)			
		0 - 15 cm	15 - 30 cm	30 - 60 cm	60 - 90 cm
Water	SE	71	51	57	49
	DW	58	50	56	57
Drainage	Natural	67	53	57	45
	Tiles	62	48	56	61
Sampling	1	84	58	71c	68
	2	52	40	43a	35
	3	58	56	56b	56

		B (µg/g)		
		0 - 30 cm	30 - 60 cm	60 - 90 cm
Water	SE	0.32	0.30	0.27
	DW	0.29	0.26	0.24
Drainage	Natural	0.29	0.28	0.26
	Tiles	0.32	0.28	0.25
Sampling	1	0.25	0.26	0.22
	2	0.33	0.26	0.25
	3	0.34	0.31	0.28

(continued)

TABLE 18. (continued)

† Values followed by the same letter are not significantly different at the α = 0.05 level according to Duncan's Multiple Range Test.

‡ Significant S x D interactions were found for total Ni at 60 to 90 cm and DTPA Mn at 15 to 30 cm.

§ Significant W x D and S x W interactions were found for DTPA Mn at 60 to 90 cm and B at 60 to 90 cm, respectively.

SE and DW refer to the application of sewage effluent and ditch water, respectively.

†† * and ** indicate significant differences at the α = 0.05 and 0.01 levels, respectively.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

TABLE 19. EFFECT OF WINTER APPLICATIONS OF THE EFFLUENT ON CHEMICAL PROPERTIES OF THE SOILS

Year	Depth 0-15 cm	15-30cm	30-60cm	60-90cm	
			Total N (%)		
1977	0.244	0.167	0.133	0.094	Depth H.S.D.$_{.05}$ = 0.032
1978	0.222	0.134	0.093	0.067	
1979	0.213	0.173	0.120	0.078	Year H.S.D.$_{.05}$ = 0.026
			NH_4^+-N (ppm)		
1977	3.4	1.3	6.3	1.5	Depth H.S.D.$_{.05}$ = 1.05
1978	5.7	3.9	3.5	3.4	
1979	8.3	6.5	4.7	5.1	Year H.S.D.$_{.05}$ = 0.72
			NO_3^--N (ppm)		
1977	7.9	2.4	6.1	0.8	Depth H.S.D.$_{.05}$ = 3.45
1978	6.0	6.2	5.0	4.4	
1979	17.8	9.7	8.9	5.0	Year H.S.D.$_{.05}$ = 3.34
			Na-HCO_3 Extractable P (ppm)		
1977	39.6	28.2	30.7	28.7	Depth H.S.D.$_{.05}$ = 3.94
1978	25.5	13.8	12.3	13.5	
1979	27.4	12.1	10.0	8.7	Year H.S.D.$_{.05}$ = 3.51
			HNO_3 Extractable Cu (ppm)		
1977	23.4	23.3	22.5	22.2	Depth H.S.D.$_{.05}$ = 1.45
1978	16.7	15.2	11.0	9.6	
1979	19.0	19.2	14.4	12.1	Year H.S.D.$_{.05}$ = 1.01

(continued)

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.) (4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

TABLE 19. (continued)

Year	Depth 0-15cm	15-30cm	30-60cm	60-90cm	
			HNO_3 Extractable Zn (ppm)		
1977	67.8	66.9	58.6	56.3	
1978	75.5	69.4	52.7	53.4	No significant differences
1979	68.0	63.0	51.4	42.6	
			HNO_3 Extractable Ni (ppm)		
1977	25.8	24.5	23.1	23.9	Depth H.S.D.$_{.05}$ = 4.24
1978	26.3	24.9	21.2	20.2	
1979	21.6	23.5	16.9	13.6	Year H.S.D.$_{.05}$ = 3.83
			HNO_3 Extractable Mn (ppm)		
1977	314	303	279	322	Depth H.S.D.$_{.05}$ = 21.94
1978	267	233	206	197	
1979	250	232	208	177	Year H.S.D.$_{.05}$ = 18.35
			DTPA Extractable Fe (ppm)		
1977	84.0	58.0	71.0	68.0	Depth H.S.D.$_{.05}$ = 4.96
1978	59.4	53.2	47.0	69.2	
1979	30.0	33.5	35.3	35.4	Year H.S.D.$_{.05}$ = 4.20
			DTPA Extractable Zn (ppm)		
1977	2.70	1.70	1.30	1.20	Depth H.S.D.$_{.05}$ = 0.25
1978	1.98	1.26	0.57	0.74	
1979	1.38	0.88	0.49	0.27	Year H.S.D.$_{.05}$ = 0.20

(continued)

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.) (4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

TABLE 19. (continued)

Year	Depth 0-15cm	15-30cm	30-60cm	60-90cm	
			DTPA Extractable Cu (ppm)		
1977	2.40	2.30	2.30	2.70	Depth H.S.D.$_{.05}$ = 0.22
1978	2.62	2.64	1.72	1.54	
1979	2.33	2.50	1.85	1.49	Year H.S.D.$_{.05}$ = 0.20
			DTPA Extractable Mn (ppm)		
1977	33.0	17.0	13.0	14.0	Depth H.S.D.$_{.05}$ = 13.50
1978	49.8	33.6	23.3	33.2	
1979	22.1	22.4	23.8	23.6	Year H.S.D.$_{.05}$ = 10.51
			NH_4OAC Extractable Na (m.e./100 g)		
1977	0.45	0.40	0.39		Depth H.S.D.$_{.05}$ = 0.22
1978	0.73	0.79	0.68	0.67	
1979	0.67	0.66	0.68	0.67	Year H.S.D.$_{.05}$ = 0.22
			NH_4OAC Extractable K (m.e./100 g)		
1977	0.99	0.74	0.56		Depth H.S.D.$_{.05}$ = 0.07
1978	0.82	0.53	0.23	0.20	
1979	0.92	0.68	0.44	0.27	Year H.S.D.$_{.05}$ = 0.06
			NH_4OAC Extractable Ca (m.e./100 g)		
1977	17.0	20.0	23.3		Depth H.S.D.$_{.05}$ = 3.19
1978	18.1	21.2	19.5	8.7	
1979	14.5	12.9	14.4	10.9	Year H.S.D.$_{.05}$ = 2.51

(continued)

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA. OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE
6-1/2"
9-1/8"

TABLE 19. (continued)

Year	Depth 0-15cm	15-30cm	30-60cm	60-90cm	
			NH_4OAC Extractable Mg (m.e./100 g)		
1977		6.3	6.5	8.6	Depth H.S.D.$_{.05}$ = 0.82
1978	6.6	6.8	4.6	3.6	
1979	8.5	8.0	7.1	5.7	Year H.S.D.$_{.05}$ = 1.47
			EC (mmhos/cm)		
1977	1.77	0.84	0.57	0.51	
1978	0.84	0.68	0.54	0.55	
1979	-	0.42	0.30	0.41	
			pH		
1977		7.0	7.3	7.4	
1978	7.3	7.4	7.5	7.3	
1979	-	7.1	7.3	7.5	

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.) (4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

with depth in 1977 and 1979 but not in 1978. The amounts of NO_3-N in the profile, though different, would not be significant in relation to plant growth because the quantities were relatively small for optimum plant growth. The addition of ferilizer N would be required.

Sodium Bicarbonate Extractable Phosphorus --

The P content of the profile greatly decreased from 1977 to 1978 in all depths except the 60 to 90 cm depth. There was little difference from 1978 to 1979 except at the 60 to 90 cm depth. The only plausible reason for the decrease in extractable P from the fall, 1977 when the initial soil samples were taken, to the fall, 1978 when soil samples were taken again, was the growth of weeds that took place during the summer of 1978. These weeds were pulled and removed during the fall of 1978 after which the furrows were again formed.

Nitric Acid Extracable Metal --

There was a general decrease in each of these metals from 1977 to 1979 although at some depths the decrease from one year to the next was not significant at the 0.05 level. The greatest decrease was between the 1977 data and the 1978 data, especially so with Cu and Mn. There were no significant differences in Zn as affected by year or depth data. The reason for the decrease in the HNO_3 extractable metals of these plots was not readily apparent because the weed growth occurring on the plots would not be sufficient to decrease the quantities of the metals to the extent shown by the data. Variations in analytical technique were minimized since the same technicians and techniques were used for all samples.

DTPA Extractable Metals --

Similar to the total metal data, there was also a general decrease in DTPA extractable metals except for Cu and Mn where the patterns cross over in an inconsistent manner.

In no case did the total or extractable quantities reach a level that was of concern either from an environmental or plant growth point of view.

Ammonium Acetate Extractable Cations --

The NH_4OAc extractable Na increase in 1978 and 1979 were comparable to the 1977 value but the total quantity was relatively low. The opposite was true of K in that there was a decrease in 1978 and 1979 compared to 1977. Again, however, the quantities of extractable K were small. Extractable Ca and Mg were much higher than the Na and K. The sodium adsorption ratio (SAR) was less than 0.2 in most cases. This may have accounted for the excellent physical condition of the soil and high infiltration and permeability rates. The variation with depth and year were significant in a number of cases but the patterns were not particularly meaningful. None of the

BEGIN LAST LINE OF TEXT HERE
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

concentrations of these four elements were in quantities that were of concern because there were not consistent increases. They were all within the normal range found in soils.

Electrical Conductivity and pH --

The EC and pH did not change significantly during the study. Both were in the normal range found in the soils of that area ranging from an EC of 0.3 to 0.8 mmhos/cm and pH of 7.0 to 7.5, respectively.

Chemical Analyses of Groundwater

Tables 20 and 21 show the chemical data obtained from the ceramic cup devices and the open wells from the six winter plots. Since the furrow configuration caused no significant differences in any of the chemical parameters measured, the mean values that comprise the table were a mean of six replications in most cases except when water samples were not obtainable from the cups nearest the soil surface. There were times when no water samples were obtained in the ceramic cups even when the vacuum was left on the tubes overnight.

Electrical Conductivity --

The EC of the soil water samples ranged from 0.29 up to 1.4 mmhos/cm. This range was a normal range for many soils in the Yampa Valley of Colorado. There were both monthly variations and depth variations in both years of the study but the only pattern that was occasionally manifested in the data was a higher EC value in the second depth from the surface than the first depth. The reason the EC data in April, 1978 were significantly lower than for other samplings is not known. In most cases, the EC of the soil water was higher than the EC of the effluent that was added to the plots. This likely resulted from the dissolution of elements or salts from mineral particles or precipitates occurring in the soil. This dissolution would also have occurred if normal irrigation water had been used as was indicated in the summer study, therefore the increase in salts did not indicate a detrimental factor associated with effluent application to land beyond that of typical irrigation water use.

Salts --

The ions, Cl, Ca, Mg, Na, K, though not the only ones that affect EC do play a major role in influencing the total salt content of soils in the area. It is not surprising therefore to see a close correlation between EC and these particular ions. Again in most cases the content of the ions in the effluent were lower than the content of the ions in the soil water for reasons outlined in the previous section. The major exception to this generalization is K. The effluent samples were higher than the soil samples. This would indicate that the effect of effluent application on K content of soil water is more like that of NH_4-N as noted in a following section than like Ca,

TABLE 20. EFFECT OF WINTER APPLICATION OF EFFLUENT ON CHEMICAL PROPERTIES OF THE SOIL WATER (MEANS OF 6 REPLICATIONS 1977-1978).

Date	Depth	1 EC	2 Cl	3 Ca	4 Hg	5 Na	6 K	7 P	8 NH_4-N	9 NO_3-N	10 BOD	11 COD	12 FS	13 FC	14 TC
		mmhos/cm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	mg/l	mg/l	no./100 ml	no./100 ml	no./100 ml
Jan. 27	1	1.28	45.9	64.3	68.6	123.3	2.8	0.59	1.4	1.6	-	-	-	-	-
	2	1.40	60.5	101.8	98.5	190.0	1.7	0.15	0.04	1.0	-	-	-	-	-
	3	0.68	41.8	59.1	67.3	94.6	2.7	0.21	0.9	0.7	-	-	-	-	-
	Open Well	1.31	29.3	53.8	60.7	72.1	2.2	0.15	0.3	0.7	-	-	834	1,243	1,617
	Effluent	0.3	29.0	43.0	17.0	57.5	8.0	0.35	5.2	0.03	-	-	60,000	60,000	60,000
Feb. 23	1	-	-	-	-	-	-	-	-	-	--	--	--	- --	--
	2	1.04	59.4	3.3	28.8	13.4	3.0	0.96	2.1	0.3	-	-	-	-	-
	3	1.09	42.3	12.6	21.3	9.6	2.0	0.07	1.3	0.3	-	-	-	-	-
	Open Well	1.06	38.5	8.8	20.9	8.1	2.2	0.16	2.2	0.3	12.4	73	734	2,169	3,922
	Effluent	0.6	38.0	18.5	5.8	6.7	7.1	4.4	8.8	0.17	36	107	60,000	60,000	60,000
March 16	1	0.93	27.1	45.5	12.9	111.0	3.2	0.16	1.1	0.4	-	-	-	-	-
	2	1.21	46.6	52.3	31.5	168.3	1.9	0.11	1.1	0.1	-	-	-	-	-
	3	0.90	35.7	67.9	21.5	88.8	1.4	0.17	1.3	0.3	-	-	-	-	-
	Open Well	0.72	34.3	40.3	18.3	84.0	1.1	0.17	1.1	0.2	5.5	68	882	1,314	5,259
	Effluent	0.71	29.5	37.5	9.3	60.0	5.8	2.6	4.3	0.04	19	92	11,000	120,000	900,000
April 12	1	0.38	37.1	59.0	17.7	115.0	2.5	0.1	0.9	2.6	-	-	-	-	-
	2	0.29	44.4	33.1	26.7	103.8	1.9	0.03	0.7	0.5	-	-	-	-	-
	3	0.45	33.8	59.2	17.7	85.0	1.4	0.02	0.8	0.1	-	-	-	-	-
	Open Well	0.43	31.5	98.5	16.4	75.4	1.3	0.03	0.7	1.7	8.5	47	75	47	121
	Effluent	0.44	42.0	145.0	2.8	85.2	5.6	1.4	2.5	0.1	20	49	1,800	12,000	86,000
$HSD_{.05}$ *		0.39	7.01	38.72	17.91	54.15	-	0.18	NS	0.50					

- Indicates the data were not available.

* $HSD_{0.5}$ - honest significance difference at the 95% levels of probability.

TABLE 21. EFFECT OF WINTER APPLICATION OF EFFLUENT ON CHEMICAL PROPERTIES OF THE SOIL WATER (MEANS OF 6 REPLICATIONS 1978-1979).

Date	Depth	1 EC	2 Cl	3 Ca	4 Mg	5 Na	6 K	7 P	8 NH_4-N	9 NO_3-N	10 BOD	11 COD	12 FS	13 FC	14 TC
		mmhos/cm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	mg/l	mg/l	no./100 ml	no./100 ml	no./100 ml
Dec. 18	1	0.84	34.0	-	-	-	-	0.25	0.72	1.65	-	-	-	-	-
	2	-	36.0	-	-	-	-	-	-	-	-	-	-	-	-
	3	0.76	30.3	-	-	-	-	0.21	0.39	0.51	-	-	-	-	-
	Open Well	0.90	35.0	-	-	-	-	0.23	0.62	6.13	-	28	521	2,020	2,267
	Effluent	0.66	3.21	-	-	-	-	2.61	4.90	6.03	-	118	370,000	64,000	79,000
Jan. 16	1	1.04	36.0	-	-	-	-	-	-	-	-	-	-	-	-
	2	1.30	20.0	-	-	-	-	0.50	1.04	-	-	-	-	-	-
	3	0.99	33.0	-	-	-	-	0.05	1.14	0.76	-	-	-	-	-
	Open Well	0.96	38.0	-	-	-	-	0.10	3.61	0.62	3.64	21	12,435	22,940	80,493
	Effluent	0.50	28.0	-	-	-	-	2.28	8.53	0.04	36	114	61,000	410,000	1,400,000
Feb. 20	1	-	-	-	-	-	-	0.38	0.62	4.70	-	-	-	-	-
	2	-	-	-	-	-	-	0.10	0.93	2.86	-	-	-	-	-
	3	-	-	-	-	-	-	0.12	1.00	0.60	-	-	-	-	-
	Open Well	-	-	-	-	-	-	0.50	3.24	1.18	4.80	-	13,433	55,147	171,333
	Effluent	-	-	-	-	-	-	2.51	10.47	0.05	48	103	79,000	220,000	4,700,000
March 18	1	0.92	18.8	45	56	122	2.3	0.17	-	2.38	-	-	-	-	-
	2	0.98	18.8	46	46	67	3.5	0.32	1.79	1.46	-	-	-	-	-
	3	0.79	21.8	61	45	76	2.7	0.13	1.11	0.69	-	-	-	-	-
	Open Well	0.67	12.6	41	35	59	3.4	0.44	1.58	2.01	1.58	37	5,425	7,125	71,975
	Effluent	0.72	24.1	71	24	71	5.5	2.75	5.48	0.04	22	59	46,000	46,000	16,000,000
April 19	1	0.58	16.0	49	29	44	4.0	0.27	0.40	-	-	-	-	-	-
	2	0.78	18.2	52	40	59	2.2	0.24	0.09	-	-	-	-	-	-
	3	0.65	18.5	49	36	41	2.0	0.10	0.19	-	-	-	-	-	-
	Open Well	0.75	25.0	58	31	63	5.0	0.18	0.19	-	4.95	32	3,217	4,550	40,083
	Effluent	-	-	-	-	-	-	0.69	0.09	0.12	10	63	8,600	270,000	300,000

- Indicates the data were not available.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA

Mg or Na. It was obvious that the values for Ca on the February 1978 samples were inordinately low and the Ca values for the April 1978 samplings effluent was much too high.

DROPPED HEAD; BEGIN SECTIONS HERE

Phosphorus --

There was a considerable decrease in the P content of the soil water compared to the added effluent as was expected. Typically there was little P movement through the soil because it was adsorbed strongly on the soil colloids if the soil texture is finer than sandy. In most cases there was a ten-fold decrease but not in all cases. There was also a tendency for the soil water obtained through the ceramic cups near the soil surface to be higher in P than that water taken from the deeper cups. This appears reasonable since that is where most of the P in the soil will be located as indicated by the soil chemical data found in Table 19.

Ammonium --

Ammonium was the ion of greatest concern in the Hayden effluent, although the summer season was the period during which there was greatest concern. There was a decrease in the NH_4-N level in the soil water compared to the added effluent. In most cases, there was a five to ten-fold decrease. In a couple of cases, the decrease was not as dramatic. In no case however. was the NH_4-N concentration in the soil water, which would eventually make its way to the stream and river, higher than 3.6 ppm. In all but four incidents, the NH_4-N content of the soil water was below 2 ppm.

Nitrate --

The effluent content of NO_3-N in the winter months generally was below 0.2 ppm. This was about the same NO_3-N level as the irrigation water used on the summer plots. Little N was added by effluent in the NO_3-N forms because of the slow rate of nitrification in the lagoon during the cold months of the year. It can be noted that the NO_3-N content of the soil water was higher in all cases than the NO_3-N content of the effluent. This indicated that some nitrification was taking place in the winter in the unfrozen soil below the snow cover. Although the rate of nitrification was slow, it was proceeding. The highest NO_3-N content of the soil water during the winter months was 4.7 ppm which was well below the minimum standard for drinking water.

BOD --

A range of about 1.5 to about 12 mg/ℓ of BOD was found in the water from open wells in the soil. This was near the range of the BOD of the irrigation water used on the summer plots but was higher than the soil water samples obtained in the summer. A two to ten-fold decrease in BOD resulted from land application compared to the BOD of the added effluent.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.) (4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD. BEGIN SECTIONS HERE

The adsorptive capacity of the soil colloids and filtering capacity of the soil mass generally cause the organic particles to remain in the soil, with only small amounts of soluble organic compounds to move through the soil profile.

It can be noted that as the winter proceeded from February to April, the BOD of the effluent tended to decrease. Increasingly warmer weather probably allowed greater decomposition and stabilization of the sewage as it flowed through the aeration lagoon and the polishing pond.

COD --

The COD of the sewage effluent ranged from 49 to 118 mg/l with the COD also decreasing as the winter proceeds. The land treatment caused the COD to decrease to a range of 21 to 73 mg/l or a mean decrease of about 50%. This range was a little higher than that of the irrigation water used in the summer study but not greatly different. As was true of BOD, there was a general decrease in COD of the added effluent as the winter proceeded. Again the COD decrease was not quite as great in the winter as in the summer, however, it was not high enough to cause serious pollution problems.

Indicator Organisms --

As shown in Tables 20 and 21, the percentage of decrease in the numbers of these groups of indicator organisms due to soil treatment ranged from 63 to 99.8 with greater decreases during the first year than the second for the most part. This result raises the question as to the possibility of continued decrease in the ability of the soil to control these groups of organisms. It is possible that some organisms may persist in the soil over extended periods of time once large numbers have been added by the effluent. Although arbitrary, it would appear that a decrease of greater than 90% would be considered quite satisfactory but below that may not be adequate. In 1977 and 1978, all samples showed greater than 90% decrease in the number of organisms whereas in 1978 and 1979 there were seven incidents shown in Table 20 where the decreases in organism numbers were less than the 90% of the numbers of organisms in the effluent.

The number of organisms in the effluent and in the soil water of this winter study were higher than the counts of the summer study. This was an unexpected result since the cold temperatures of the winter effluent would tend to inhibit organism population proliferation. The reason for such a result is not apparent at the moment.

Metals --

The contents of Cd, Cu, Zn, Ni, and Mn were all so low in the effluent and in the soil water that they were far below the level of concern from a pollution standpoint. For typical values see the section on trace metals and micronutrients in the summer

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
study. They were typical of the values obtained in the winter study also.
DROPPED HEAD; BEGIN SECTIONS HERE
6-1/2"
9-1/8"
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
79
PAGE NUMBER

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE

BIBLIOGRAPHY

Adriano, D.C., L.T. Novak, A.E. Erickson, A.R. Wolcott, and B.G. Ellis. 1975. Effect of long-term land disposal by spray irrigation of food processing wastes on some chemical properties of the soil and subsurface water. J. Environ. Qual. 4:242-248.

Alexander, Martin. 1977. Introduction to Soil Microbiology. Second ed., John Wiley and Sons, New York.

Andrew, Roger C. and A. Paul Troemper. 1977. Underflow from sludge-irrigated cropland. J. Water Poll. Control Fed. 49:161-168.

American Public Health Association. 1975. Standard Methods for the Examination of Water and Wastewater. 14th ed., Washington, D.C.

Armstrong, D.L., J. Barrelli, and R.D. Burman. 1978. Land application of wastewater for treatment and disposal. The Thayne, Wyoming Experience. Proceedings Rocky Mountain Region Meeting, Am. Soc. Agr. Eng., Denver, CO. Feb. 10.

Appelt, H., K. Holtzclaw, and P.F. Pratt. 1975. Effect of anion exclsuion on the movement of chloride through soils. Soil Sci. Soc. Amer. Proc. 39:264-267.

Barton, C.J. 1948. Photometric analysis of phosphate rock. Analy. Chem. 20:1068-1073.

Beck, J., G.A.M. deHaan, and L.J. Riemadylz. 1977. Phosphates in soils treated with sewage water: I. General information on sewage farm, soil, and treatment results. J. Environ. Qual. 6:4-7.

Bell, R.G. 1976. Persistence of fecal coliform indicator bacteria on alfalfa irrigated with municipal sewage lagoon effluent. J. Environ. Qual. 5:39-42.

Bell, R.G. and J.B. Bole. 1976. Elimination of fecal coliform bacteria from reed canary grass irrigated with municipal sewage lagoon effluent. J. Environ. Qual. 5:417-418.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.) (4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

Bell, R.G., and J.B. Bole. 1978. Elimination of fecal coliform bacteria from soil irrigated with municipal sewage lagoon effluent. J. Environ. Qual. 7:193-196.

Bitton, G., J. Masterson, and G.E. Gifford. 1976. Effect of secondary treated effluent on the movement of viruses through a Cypress dome soil. J. Environ. Qual. 5:370-375.

Bouwer, H. 1968. Returning wastes to the land, a new role for agriculture. J. Soil & Water Cons. 23:164-168.

Bouwer, H. 1973. Land treatment of liquid waste: The hydrologic system. pp. 103-111. In Recycling Municipal Sludges and Effluents on Land. Natl. Assoc. of State Univ. and Land Grant Colleges, Washington, D.C.

Bouwer, H., and R.L. Chaney. 1974. Land treatment of wastewater. Adv. Agron. 26:133-176.

Bouwer, C.A., and L.V. Wilcox. 1965. Soluble salts. pp. 933-951. In C.A. Black, D.D. Evans, J.L. White, L.E. Ensminger, and F.E. CLark (eds.) Methods of Soil Analyses, Part II. Soil Sci. Soc. Am., Madison, WI.

Bradford, G.R., A.L. Page, L.J. Lund, and W. Olmstead. 1975. Trace element concentrations of sewage treatment plant effluents and sludges; their interactions with soils and uptake by plants. J. Environ. Qual. 4:123-127.

Bremmer, J.M. 1965. Total nitrogen. pp. 1149-1178. In C.A. Black et al. (eds). Methods of Soil Analyses, Part II. Soil Sci. Soc. Am., Madison, WI.

Bremmer, J.M. 1965. Inorganic forms of nitrogen. pp. 1179-1237. In C.A. Black et al. (eds.) Methods of Soil Analyses, Soil Sci. Soc. Am., Madison, WI.

Bresler, E. 1967. A model for tracing salt distribution in the soil profile and estimating the efficiency combination of water quality and quantity under varying field conditions. Soil Sci. 104:227-233.

Bresler, E. 1973. Solute movement in soils. pp. 165-175. In B. Yaron, E. Danfors, and Y. Vaadia (eds.) Arid Zone Irrigation, Springer-Verlag, New York.

Burge, W.D., and N.K. Enkiri. 1978. Virus adsorption by five soils. J. Environ. Qual. 7:73-76.

Burge, W.D., and P.B. Marsh. 1978. Infectious disease hazards of landspreading sewage wastes. J. Environ. Qual. 7:1-9.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.) (4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE
6-1/2"
9-1/8"
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

Campbell, I.S., and A.D. Dotzenko. 19 . Evaluating forage quality of pastures. J. Range Manage. 28:149-151.

Cassel, D.K., T.H. Krueger, F.W. Schroer, and E.B. Norum. 1974. Soluble movement through disturbed and undisturbed soil cores. Soil Sci. Soc. Amer. Proc. 38:36-40.

Chaney, R.L. 1973. Crop and food chain effects of toxic elements in sludges and effluents. pp. 129-141. In Natl. Assoc. State Univ. and Land Grant Colleges, Recycling Municipal Sludges and Effluents on Land, Washington, D.C.

Chapman, H.D. 1965. Total exchangeable bases. pp. 902-904. In C.A. Black, E.E. Evans, L.E. Ensminger, and F.E. Clark (eds.) Methods of Soil Analyses, Part II, Soil Sci. Soc. Amer., Madison, WI.

Chapman, K.D. (ed.) 1966. Diagnostic Criteria for Plants and Soils. Univ. of California, Div. of Agric. Sci. Berkely, CA.

Chumbley, C.G. 1971. Permissible levels of toxic metals in sewage used on agricultural land. A.O.A.S. Advisory Paper No. 10. 12 pp.

Cornwell, D.A., J. Zoltek, Jr., C.D. Patrinely, T. des Furman, and J.I. Kin. 1977. Nutrient removal by water hyacinths. J. Water Poll. Control Fed. 49:57-65.

Dalton, F.E., J.E. Stein, and B.T. Lyman. 1968. Land reclamation - A complete solution of the sludge and solids disposal problem. J. Water Poll. Control Fed. 40:789-804.

Davis, S.N., and R.J.M. De Wiest. 1966. Hydrogeology. John Wiley and Sons Inc., New York.

Day, A.D., and R.M. Kirkpatrick. 1973. Effects of treated municipal wastewater on oat forage and grain. J. Environ. Qual. 2:282-283.

Day, A.D., A. Ralunan, F.R.H. Katterman, and V. Jensen. 1974. Effects of treated municipal wastewater and commercial fertilizer on growth, fiber, acid-soluble nucleotides, protein and amino acid content in wheat hay. J. Environ. Qual. 3:17-19.

Day, A.D., F.A. Johner, and F.R.H. Kotterman. 1975. Influence of treated municipal wastewater on growth, fiber, acid-soluble nucleotides, protein and amino acid content in wheat grain. J. Environ. Qual. 4:167-169.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

Duke, H.R., and H.R. Haise. 1973. Vacuum extractors to assess deep percolation losses and chemical constituents of soil water. Soil Sci. Soc. Amer. Proc. 37:963-964.

Duxbury, J.M., and J.M. Peverly. 1978. Nitrogen and phosphorus losses from organic soils. J. Environ. Qual. 7:566-570.

Elliott, L.F., and J.R. Ellis. 1977. Bacterial and viral pathogens associated with land application or organic wastes. J. Environ. Qual. 6:245-251.

Enfield, C.G. 1974. Rate of phosphorus sorption of five Oklahoma soils. Soil Sci. Soc. Amer. Proc. 38:404-407.

Enfield, C.G. 1977. Servo controlled optimization of nitrification-denitrification of wastewater in soil. J. Environ. Qual. 6:456-468.

Ghuman, B.S., S.M. Verna, and S.S. Prihar. 1975. Effect of application rate, initial soil wetness, and redistribution time on salt displacement of water. Soil Sci. Soc. Amer. Proc. 39:7-10.

Gilbert, R.G., C.P. Gerba, R.C. Rice, H. Bouwer, C. Wallis, and J.L. Melnick. 1976. Virus and bacteria removal from wastewater by land treatment. Appl. Environ. Microbiol. 32:333-338.

Greenberg, A.E., and J.F. Thomas. 1954. Sewage effluent reclamation for industrial and agricultural use. Sewage and Industrial Wastes 26:761-770.

Hanway, J.J., J.B. Herrick, and T.L. Willvich, P.C. Bennett, and J.T. McCall. 1963. The nitrate problem. Spec. Rept. No. 34. Iowa State University, Ames.

Hansen, E.A., and A.R. Harris. 1975. Validity of soil-water samples collected with porous ceramic cups. Soil Sci. Soc. Amer. Proc. 39:528-536.

Harris, A., and E. Hansen. 1975. A new ceramic cup soil water sampler. Soil Sci. Soc. Amer. Proc. 39:157-168.

Hassett, J.J., and J.J. Jurinak. 1971. Effect of Mg^{2+} ion on the solubility of solid carbonates. Soil Sci. Soc. Amer. Proc. 35:403-406.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

Henry, C.D., R.D. Moldenhauer, L.E. Englebert, and E. Truog. 1954. Sewage effluent disposal through crop irrigation. Sewage and Industrial Wastes 26:123-135.

Hook, J.E., and L.T. Kardos. 1978. Nitrate leaching during long-term spray irrigation of secondary sewage effluent on woodland sites. J. Environ. Qual. 7:30-34.

Hortenstine, C.C. 1976. Chemical changes in the soil solution from a Spodosol irrigated with secondary-treated sewage effluent. J. Environ. Qual. 5:335-338.

Iskandar, I.K. 1978. The effect of wastewater reuse in cold regions on land treatment systems. J. Environ. Qual. 7:361-368.

John, M.K., H.H. Chuah, and J.H. Newfield. 1975. Application of improved asomethine-H method to the determination of boron in soils and plants. Analytical Letters 8(8):559-568.

Jones, J.H., and G.S. Taylor. 1965. Septic tank effluent percolation through sands under laboratory conditions. Soil Sci. 99:301-309.

Kardos, L.T., and J.E. Hook. 1976. Phosphorus balance in sewage effluent treated soils. J. Environ. Qual. 5:76-90.

Lagerwerff, J.V. 1972. Lead, mercury, and cadmium as environmental contaminants. pp. 593-642. In J.J. Mortvedt, P.M. Giordano, and W.L. Lindsay (eds.) Micronutrients in Agriculture. Soil Sci. Soc. Amer., Madison, WI.

Lance, J.C., and F.D. Whisler. 1972. Nitrogen balance in soil columns intermittently flooded with secondary sewage effluent. J. Environ. Qual. 1:180-186.

Lance, J.C., F.D. Whisler, and H. Bouwer. 1973. Oxygen utilization in soils flooded with sewage water. J. Environ. Qual. 2:345-350.

Lance, J.C., F.D. Whisler, and R.C. Rice. 1976. Maximizing denitrification during soil filtration of sewage water. J. Environ. Qual. 5:102-107.

Lance, J.C., R.C. Rice, and F.D. Whisler. 1978. Effects of vegetation on denitrification and phosphate movement during rapid infiltration of soil columns. J. Water Poll. Control Fed. 50:2183-2188.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

Larson, W.E., J.R. Gilley, and D.R. Linden. 1975. Consequences of waste disposal on land. J. Soil & Water Cons. 30:68-71.

Lehman, G.S. and L.G. Wilson. 1971. Trace element removal from sewage effluent by soil filtration. Water Resour. Res. 7:90-99.

Lindsay, W.L. 1972. Inorganic phase equilibria of micronutrients in soils. pp. 41-57. In J.J. Mortvedt et al. (eds.) Micronutrients in Agriculture, Soil Sci. Soc. Amer., Madison, WI.

Lindsay, W.L. 1973. Inorganic reactions of sewage wastes with soils. pp. 91-96. In Natl. Assoc. of State Univ. and Land Grant Colleges, Recycling Municipal Sludges and Effluents on Land, Washington, D.C.

Lindsay, W.L. and W.A. Norvell. 1969. Changes in DTPA extractable zinc, iron, manganese, and copper in soils following fertilization. Soil Sci. Soc. Am. Proc. 35:600-602.

Lindsay, W.L. and W.A. Norvell. 1978. Development of a DTPA soil test for zinc, iron, manganese, and copper. Soil Sci. Soc. Am. J. 42:421-428.

Ludwick, A.E., and C.B. Rumberg. 1976. Grass hay production as influenced by N-P topdressing and by residual P. Agron. J. 68:933-937.

Ludwick, A.E., C.B. Rumberg, and E.G. Siemer. 1978. Nitrogen sources for hay production on flooded meadows. Soil Sci. Soc. Am. J. 42:509-512.

Luley, H.G. 1963. Spray irrigation of vegetable and fruit processing wastes. J. Water Poll. Control Fed. 35:1252-1261.

Miller, D.E., F.M. Willhite, and H.K. Rouse. 1955. High altitude meadows in Colorado: II. The effect of harvest date on yield and quality of hay. Agron. J. 47:69-72.

Miller, R.H. 1973. Soil microbiological aspects of recycling sewage sludges and waste effluents on land. pp. 79-90. In Natl Assoc. State Univ, and Land Grant Colleges, Recycling Municipal Sludges and Effluents on Land, Washington, D.C.

Peech, M. 1965. Hydrogen-ion activity. pp. 914-926. In C.A. Black (eds.) Methods of Soil Analyses, Part II, Soil Sci. Soc. Am., Madison, WI.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE
6-1/2"
3/8"
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.) (4-76)

Perkin-Elmer Corporation. 1971. Analytical methods for atomic absorption spectrophotometry. Norwalk, Connecticut.

Pound, C.E., and R.W. Crites. 1973. Characteristics of municipal effluents. pp. 49-59. In Natl Assoc. of State Univ. and Land Grant Colleges, Recycling Municipal Sludges and Effluents on Land, Washington, D.C.

Powers, W.L., G.W. Wallingford, and L.S. Murphy. 1975. Formulas for applying organic wastes to land. J. Soil & Water Cons. 30:286-289.

Purtymum, W.D., J.R. Bucholz, and T.E. Hakonson. 1977. Chemical quality of effluents and their influence on water quality in a shallow aquifer. J. Environ. Qual. 7:29-32.

Robbins, C.W., and J.H. Smith. 1977. Phosphorus movement in calcareous soils irrigated with wastewater from potato processing plants. J. Environ. Qual. 6:222-225.

Rouse, H.K., R.M. Willhite, and D.E. Miller. 1955. High altitude meadows in Colorado: I. Effect of irrigation on hay yield quality. Agron. J. 47:36-40.

Sawhney, B.L. 1977. Predicting phosphate movement through soil columns. J. Environ. Qual. 6:86-89.

Sidle, R.C., J.E. Hook, and L.T. Kardos. 1976. Heavy metal application and plant uptake in a land disposal systems for wastewater. J. Environ. Qual. 5:97-102.

Sidle, R.C., and W.E. Sopper. 1976. Cadmium distribution in forest ecosystems irrigated with treated municipal wastewater and sludge. J. Environ. Qual. 5:419-422.

Sidle, R.C., J.E. Hook, and L.T. Kardos. 1977. Accumulation of heavy metals in soils from extended wastewater irrigation. J. Water Poll. Control Fed. 49:311-318.

Sidle, R.C., and L.T. Kardos. 1977a. Adsorption of copper, zinc, and cadmium by a forest soil. J. Environ. Qual. 6:313-317.

Sidle, R.C., and L.T. Kardos. 1977b. Transport of heavy metals in a sludge-treated forested area. J. Environ. Qual. 6:431-437.

Sidle, R.C., J.T. Kardos, and M. Th. van Genuchten. 1977. Heavy metals transport model in a sludge-treated soil. J. Environ. Qual. 6:438-443.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

Sorber, C.A.H., T. Basum, S.A. Schaub, and M.J. Small. 1976. A study of bacterial aerosols at a wastewater irrigation site. J. Water Poll. Control Fed. 49:311-318.

Starr, J.L., F.E. Broadbent, and D.R. Nielsen. 1974. Nitrogen transformations during continuous leaching. Soil Sci. Soc. Amer. Proc. 38:238-239.

Steel, R.G., and J.H. Torrie. 1960. Principles and Procedures of Statistics. McGraw-Hill, New York.

Street, J.J., W.L. Lindsay, and B.R. Sabey. 1977. Solubility and uptake of cadmium in soils amended with cadmium and sewage sludge. J. Environ. Qual. 6:72-77.

Stone, R., and J.C. Merrell, Jr. 1958. Significance of minerals in wastewater. Sewage and Industrial Wastes. 30:928-936.

Sutton, D.L., and W.H. Ornes. 1975. Phosphorus removal from static sewage effluent using duckweed. J. Environ. Qual. 4:367-370.

Tecator. Undated. Tecator Manual. Digestion System DS40.

Thompson, L.G. 1976. Forage Quality Evaluation of Irrigated Pastures. Ph.D. Dissertation, Department of Agronomy, Colorado State University, Fort Collins.

Tilstra, J.R., K.W. Maleug, and W.C. Larson. 1972. Removal of phosphorus and nitrogen from wastewater effluents by induced soil percolation. J. Water Poll. Control Fed. 44:796-805.

U.S. Public Health Service. 1962. Drinking water standards. USPHS Publ. 956-61 p.

U.S. Salinity Laboratory Staff. 1954. Diagnosis and improvement of saline and alkali soils. USDA, Agric. Handbook No. 60. L.A. Richards (ed.).

van Soest, P.J. 1963. Use of detergents in the analysis of fibrous feeds. II. A rapid method for determination of fiber and lignin. J. Assoc. Off. Anal. Chem. 46:829-835.

van Soest, P.J. 1965. Non-nutritive residues: A system of analysis for the replacement of crude fiber. J. Assoc. Off. Anal. Chem. 49:546-551.

van Soest, P.J. 1969. Basis for relationships between nutritive value and chemically identifiable fractions. pp. U1-U19. In National Conference on Forage Quality Evaluation and Utilization, Nebr. Center for Cont. Ed., Lincoln.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

van Soest, P.J., and R.H. Wine. 1967. Use of detergent in the analysis of fibrous feeds. IV. Determination of plant cell-wall constituents. J. Assoc. Off. Anal. Chem. 50:50-55.

van Soest, P.J. 1973. Composition and nutritive value of forages. In M.E. Heath, D.S. Metcalfe, and R.F. Barnes (eds.) Forages - The Science of Grassland Agriculture, 3rd Edition, The Iowa State Univ. Press, Ames.

Watanabe, F.S., and S.R. Olsen. 1965. Test of an ascorbic acid method for determining phosphorus in water and $NaHCO_3$ extracts from soils. Soil Sci. Soc. Am. Proc. 29:677-678.

Wellings, F.M., A.L. Lewis, C.W. Mountain, and L.V. Pierce. 1975. Demonstration of virus in groundwater after effluent discharge onto soil. Appl. Environ. Microbiol. 29:751-757.

Whisler, F.D., J.C. Lance, and R.S. Linebarger. 1974. Redox potentials in soil columns intermittently flooded with sewage water. J. Environ. Qual. 3:68-74.

Wilcox, L.V. 1948. Agricultural uses of reclaimed sewage effluent. Sewage Works Journal. 20:24-35.

Willhite, F.M., H.K. Rouse, and D.W. Miller. 1955. High Altitude Meadows in Colorado: III. The effect of nitrogen fertilization on crude protein production. Agron. J. 47:117-121.

BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

APPENDIX A

TABLE A1. PROFILE DESCRIPTION FOR PLOT 3.

Depth (cm)	Texture	Moist color	Structure
0.0 - 5.0	silty clay	10YR 3/3	granular
5.0 - 17.5	silty clay	10YR 4/2	massive
17.5 - 32.5	clay	10YR 4/3	massive
32.5 - 49.4	clay	10YR 4/2	massive
49.4 - 71.2	clay	10YR 3/3	massive
71.2 - 85.0	clay	mottled 10YR 3/3	massive
85.0 - 90.0	clay	10YR 3/2	massive

6-1/2"
9-1/8"

TABLE A2. PROFILE DESCRIPTION FOR PLOT 5.

Depth (cm)	Texture	Moist color	Structure
0.0 - 3.8	silty clay loam	10YR 3/2	granular
3.8 - 9.4	silty clay loam	10YR 3/2	granular
9.4 - 20.0	silty clay loam	10YR 4/2	weak sub-angular blocky
20.0 - 36.2	silty clay loam	10YR 4/2	weak sub-angular blocky
36.2 - 60.0	clay loam	10YR 4/3	massive
60.0 - 77.5	silty clay	10YR 4/2	massive
77.5 - 90.0	silty clay	10YR 4/2	massive

BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

TABLE A3. PROFILE DESCRIPTION FOR PLOT 7.

Depth (cm)	Texture	Moist color	Structure
0.0 - 1.2	silty clay loam	10YR 3/2	granular
1.2 - 10.0	silty clay loam	10YR 3/2	massive
10.0 - 27.5	silty clay loam	10YR 3/3	massive
27.5 - 41.2	silty clay loam	10YR 3/3	weak sub-angular blocky
41.2 - 61.2	heavy silty clay loam	mottled 10YR 3/3	massive
61.2 - 80.0	silty clay	mottled 10YR 4/3	massive
80.0 - 90.0	clay	mottled 10YR 4/4	massive

9-1/8"
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

TABLE A4. 1977 HYDRAULIC HEAD DATA.

Date	Location	Hydraulic Head			Date	Location	Hydraulic Head		
		120	150	180			120	150	180
		- - - cm - - -					- - - cm - - -		
6-2	1	181	166	149	6-10	1	138	128	127
	2	192	176	155		2	102	122	146
	3	171	164	151		3	205	190	143
	4	163	141	126		4	176	184	157
	5	164	172	154		5	217	217	217
6-3	1	161	158	148	6-13	1	218	218	218
	2	156	184	157		2	102	124	151
	3	131	180	158		3	198	181	158
	4	162	141	126		4	168	178	165
	5	166	155	152		5	217	217	217
6-4	1	158	156	156	6-14	1	218	218	218
	2	132	123	155		2	112	134	148
	3	154	178	159		3	205	200	197
	4	163	136	126		4	169	159	148
	5	171	155	149		5	216	216	215
6-6	1	165	155	156	6-15	1	218	218	218
	2	153	135	152		2	102	124	144
	3	183	172	151		3	203	177	157
	4	175	186	155		4	-	-	-
	5	217	217	217		5	217	217	217
6-7	1	159	156	152	6-16	1	218	218	218
	2	152	129	155		2	110	132	143
	3	179	186	163		3	189	183	176
	4	173	171	157		4	170	158	150
	5	217	217	217		5	217	217	217
6-8	1	142	129	136	6-17	1	218	218	218
	2	112	131	154		2	102	125	145
	3	197	184	164		3	185	179	161
	4	169	182	155		4	173	157	154
	5	217	217	217		5	217	217	217
6-9	1	144	137	173	6-21	1	218	218	217
	2	113	142	157		2	99	122	146
	3	187	190	155		3	193	191	175
	4	166	177	137		4	164	172	146
	5	217	217	217		5	213	212	213

(continued)

BEGIN LAST LINE OF TEXT HERE
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

TABLE A4. CONTINUED

Date	Location	Hydraulic Head			Date	Location	Hydraulic Head		
		120	150	180			120	150	180
		- - -	cm	- - -			- - -	cm	- - -
6-22	1	217	216	217	7-1	1	216	215	217
	2	100	112	146		2	120	104	115
	3	195	191	185		3	199	197	195
	4	158	173	141		4	145	172	144
	5	215	213	214		5	207	208	208
6-23	1	217	217	217	7-5	1	217	216	217
	2	174	114	122		2	122	132	142
	3	193	191	177		3	191	193	182
	4	154	180	142		4	152	170	151
	5	213	212	213		5	202	207	207
6-24	1	218	217	218	7-6	1	217	217	217
	2	180	131	164		2	167	112	-
	3	193	193	181		3	195	197	178
	4	181	182	141		4	143	163	145
	5	211	211	212		5	215	214	215
6-27	1	217	217	217	7-7	1	216	217	217
	2	152	116	145		2	154	112	-
	3	197	195	179		3	188	195	182
	4	149	170	149		4	146	166	139
	5	209	208	209		5	217	217	217
6-28	1	218	217	216	7-8	1	216	216	217
	2	143	130	121		2	156	131	-
	3	185	184	174		3	191	195	183
	4	173	174	140		4	170	166	141
	5	209	208	209		5	216	216	216
6-29	1	217	216	217	7-20	1	217	216	216
	2	118	112	132		2	-	-	-
	3	198	190	168		3	195	190	182
	4	147	172	151		4	166	163	161
	5	205	205	209		5	207	204	025
6-30	1	217	216	217	7-21	1	217	217	216
	2	117	103	122		2	-	-	-
	3	195	195	193		3	197	195	186
	4	160	185	159		4	177	172	160
	5	205	206	207		5	212	213	212

(continued)

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

TABLE A4. CONTINUED

Date	Location	Hydraulic Head			Date	Location	Hydraulic Head		
		120	150	180			120	150	180
		- - -	cm	- - -			- - -	cm	- - -
7-23	1	217	217	217	8-3	1	217	217	217
	2	125	92	-		2	80	61	-
	3	196	194	187		3	200	205	193
	4	171	172	132		4	168	169	136
	5	212	212	212		5	212	211	211
7-25	1	216	217	217	8-4	1	217	217	216
	2	117	78	-		2	102	65	-
	3	193	205	192		3	200	205	188
	4	177	171	146		4	161	159	137
	5	215	215	216		5	214	214	215
7-26	1	218	217	218	8-8	1	217	216	217
	2	116	82	-		2	122	72	-
	3	200	205	195		3	200	125	196
	4	170	171	136		4	165	162	134
	5	215	215	216		5	214	212	215
7-27	1	218	217	217	8-10	1	217	216	216
	2	117	82	-		3	199	205	196
	3	202	205	184		3	199	205	196
	4	167	170	156		4	166	163	133
	5	214	214	215		5	214	214	216
7-28	1	217	216	216	8-11	1	217	217	217
	2	115	75	-		2	124	80	-
	3	201	205	194		3	200	205	195
	4	166	166	146		4	162	161	136
	5	214	215	214		5	212	211	213
7-29	1	217	216	216	8-12	1	217	217	217
	2	112	62	-		2	118	77	-
	3	198	204	195		3	202	205	200
	4	168	166	142		4	161	159	136
	5	214	215	215		5	214	216	215
8-2	1	217	217	217	8-16	1	217	217	217
	2	107	62	-		2	118	82	-
	3	202	205	198		3	202	205	200
	4	168	165	128		4	153	157	135
	5	212	211	212		5	212	212	215

(continued)

BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
3/8"

PAGE NUMBER
EPA-287 (Cin.) (4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

TABLE A4. CONTINUED

Date	Location	Hydraulic Head			Date	Location	Hydraulic Head		
		120	150	180			120	150	180
		- - -	cm	- - -			- - -	cm	- - -
8-17	1	217	216	216	8-28	1	217	216	217
	2	110	80	-		2	122	82	67
	3	202	205	201		3	204	203	205
	4	151	158	135		4	170	149	128
	5	215	215	216		5	216	215	215
8-19	1	217	216	217	8-30	1	217	217	216
	2	100	83	-		2	133	76	56
	3	201	205	197		3	203	196	204
	4	155	151	136		4	186	151	13
	5	213	213	214		5	215	214	215
8-20	1	217	217	217	9-1	1	127	217	217
	2	117	102	-		2	136	79	64
	3	198	205	205		3	203	205	205
	4	150	155	134		4	163	150	125
	5	214	210	213		5	215	214	215
8-21	1	215	217	216	9-3	1	217	216	216
	2	128	92	62		2	135	77	62
	3	196	205	203		3	203	205	205
	4	144	149	127		4	164	171	128
	5	214	215	214		5	216	214	215
8-22	1	216	217	217	9-5	1	217	216	216
	2	122	87	72		2	128	79	67
	3	196	205	203		3	203	204	205
	4	140	141	129		4	154	145	129
	5	214	212	215		5	215	213	215
8-23	1	217	217	216	9-7	1	217	216	217
	2	115	82	67		2	132	77	70
	3	197	205	205		3	203	205	205
	4	169	150	128		4	156	147	128
	5	214	213	214		5	216	214	214
8-24	1	217	216	216	9-10	1	217	216	216
	2	112	79	70		2	141	131	126
	3	200	205	204		3	196	194	204
	4	166	156	134		4	145	148	130
	5	214	215	214		5	213	212	215

(continued)

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.) (4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD. BEGIN SECTIONS HERE

TABLE A4. CONTINUED

Date	Location	Hydraulic Head 120	150	180	Date	Location	Hydraulic Head 120	150	180
		- - - cm - - -					- - - cm - - -		
9-12	1	217	216	217	9-18	1	217	217	216
	2	135	130	114		2	132	79	63
	3	197	198	205		3	202	196	205
	4	146	147	128		4	164	160	128
	5	213	214	213		5	214	215	214
9-13	1	216	216	217	9-19	1	217	218	216
	2	152	87	71		2	148	122	78
	3	197	199	205		3	201	197	205
	4	146	158	120		4	171	170	134
	5	213	213	215		5	214	213	215
9-14	1	216	216	215					
	2	136	93	70					
	3	204	203	205					
	4	161	160	136					
	5	215	214	215					

* Locations relative to the study area are
1 = south; 2 = center; 3 = north; 4 = west; 5 = east.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE

TABLE A5. 1978 HYDRAULIC HEAD DATA

Date	Location	Hydraulic Head			Date	Location	Hydraulic Head		
		120	150	180			120	150	180
		- - - cm - - -					- - - cm - - -		
6-5	1	214	216	213	6-19	1	214	216	216
	2	128	124	120		2	200	93	54
	3	196	155	135		3	198	178	164
	4	191	153	139		4	181	149	188
	5	209	208	212		5	207	210	205
6-7	1	216	215	217	6-20	1	216	217	217
	2	192	93	114		2	187	93	54
	3	193	165	170		3	200	176	171
	4	186	166	172		4	188	153	186
	5	208	204	212		5	209	211	208
6-9	1	216	217	216	6-21	1	215	216	215
	2	191	92	43		2	193	101	61
	3	197	175	168		3	195	176	168
	4	184	152	143		4	185	154	187
	5	202	204	207		5	207	208	205
6-12	1	215	216	216	6-26	1	212	216	216
	2	192	90	57		2	197	104	70
	3	200	172	170		3	196	172	170
	4	186	159	153		4	181	138	184
	5	207	212	210		5	197	202	192
6-14	1	217	217	217	6-28	1	210	214	215
	2	192	89	51		2	190	93	61
	3	197	184	174		3	196	158	168
	4	197	167	184		4	182	147	185
	5	208	211	209		5	207	213	210
6-16	1	215	216	215	7-5	1	215	218	217
	2	186	91	53		2	188	89	53
	3	197	184	168		3	196	156	171
	4	195	165	188		4	185	133	184
	5	208	212	208		5	208	212	209
6-17	1	216	217	217	7-6	1	217	217	217
	2	183	83	43		2	191	98	67
	3	198	184	170		3	194	173	184
	4	163	161	185		4	178	141	182
	5	209	209	210		5	209	213	210

(continued)

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

TABLE A5. CONTINUED

Date	Location	Hydraulic Head 120	150	180	Date	Location	Hydraulic Head 120	150	180
		--- cm ---					--- cm ---		
7-7	1	217	216	217	7-25	1	216	217	215
	2	193	91	115		2	192	92	56
	3	195	168	180		3	194	135	178
	4	177	139	181		4	173	132	185
	5	207	214	212		5	202	214	213
7-10	1	217	217	216	7-31	1	212	214	217
	2	189	88	53		2	191	88	69
	3	192	166	176		3	196	134	173
	4	177	144	184		4	171	131	184
	5	206	211	208		5	197	204	208
7-12	1	217	217	215	8-1	1	214	216	215
	2	191	66	58		2	191	77	64
	3	194	166	181		3	198	122	183
	4	177	128	186		4	172	133	188
	5	210	214	212		5	207	208	214
7-14	1	217	216	217	8-2	1	216	217	217
	2	193	73	61		2	191	94	64
	3	196	172	183		3	198	145	184
	4	177	149	185		4	169	134	183
	5	212	214	215		5	199	206	204
7-18	1	212	211	209	8-3	1	217	217	217
	2	177	56	41		2	191	82	70
	3	200	144	184		3	196	122	180
	4	169	131	185		4	173	132	189
	5	196	202	198		5	198	214	204
7-21	1	215	215	216	8-4	1	217	217	217
	2	193	74	63		2	191	77	59
	3	201	152	176		3	200	118	182
	4	173	133	188		4	172	132	181
	5	205	210	207		5	199	213	208
7-22	1	215	216	216	8-6	1	217	217	217
	2	197	94	65		2	187	91	82
	3	195	140	182		3	195	163	177
	4	172	131	183		4	167	127	180
	5	202	204	210		5	202	212	208

(continued)

BEGIN LAST LINE OF TEXT HERE
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

TABLE A5. CONTINUED.

Date	Location	Hydraulic Head			Date	Location	Hydraulic Head		
		120	150	180			120	150	180
		- - -	cm	- - -			- - -	cm	- - -
8-9	1	214	215	215	9-9	1	217	216	217
	2	189	97	85		2	195	93	105
	3	197	116	180		3	200	123	182
	4	164	131	183		4	183	87	181
	5	205	213	209		5	198	206	204
8-11	1	215	217	217	9-10	1	217	125	213
	2	189	98	88		2	197	89	55
	3	196	120	179		3	200	132	180
	4	166	133	186		4	187	127	185
	5	207	214	208		5	198	204	200
8-15	1	207	215	124	9-19	1	209	213	207
	2	193	97	57		2	193	91	82
	3	200	136	182		3	201	158	185
	4	168	131	182		4	186	195	182
	5	198	208	204		5	206	213	208
8-16	1	217	217	213	9-21	1	213	212	211
	2	192	89	65		2	194	91	82
	3	193	105	189		3	200	178	182
	4	173	134	182		4	187	195	192
	5	204	211	206		5	208	214	207
8-28	1	214	217	216	9-27	1	216	215	214
	2	197	92	82		2	205	87	52
	3	195	80	180		3	200	178	182
	4	161	134	186		4	182	163	179
	5	198	207	204		5	205	208	202
9-5	1	217	216	217	9-29	1	217	217	213
	2	188	98	70		2	205	91	53
	3	201	73	185		3	202	181	184
	4	202	125	182		4	183	165	184
	5	207	212	208		5	207	211	206
9-7	1	216	215	216					
	2	191	98	71					
	3	197	76	182					
	4	203	127	179					
	5	208	210	206					

* Locations are 1 = south, 2 = center, 3 = north, 4 = west, and 5 = east.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA

TABLE A6. 1977 GROUNDWATER ELEVATIONS WITH RESPECT TO THE REFERENCE LEVEL.

DROPPED HEAD; BEGIN SECTIONS HERE

Date	Groundwater Elevations, Plots								
	1	2	3	4	5	6*	7*	8*	9*
	cm								
6/ 2	199	203	213	188	156	167	186	158	153
6/ 3	189	188	211	196	175	162	176	154	182
6/ 4	190	180	184	194	174	175	168	160	183
6/ 6	173	195	172	185	169	177	169	183	160
6/ 7	184	205	183	195	180	169	191	831	176
6/ 8	181	194	194	189	185	168	160	183	173
6/ 9	192	212	183	199	192	183	172	188	169
6/10	196	206	192	197	195	198	186	196	153
6/13	162	192	173	155	165	167	143	176	150
6/14	187	204	197	187	184	174	156	171	150
6/15	179	199	185	183	181	179	156	180	164
6/16	179	199	185	183	181	179	156	180	164
6/17	186	204	187	187	188	178	165	182	170
6/21	179	179	178	175	147	156	154	175	166
6/22	182	171	195	175	172	166	166	168	147
6/23	186	178	191	181	172	170	161	169	155
6/24	191	198	209	182	177	174	170	168	186
6/27	152	146	162	151	142	146	139	153	160
6/28	177	168	177	165	165	159	143	174	150
6/29	181	181	177	172	172	164	163	169	159
6/30	174	177	172	163	162	166	159	170	158
7/ 1	173	180	183	164	183	182	195	175	159
7/ 5	163	159	161	151	152	183	139	135	133
7/ 6	162	168	178	159	150	182	146	147	153
7/ 7	175	193	189	187	169	174	172	178	155
7/ 8	192	194	189	179	180	169	109	188	179
7/20	124	127	145	124	124	135	118	127	128
7/21	127	147	157	130	128	134	127	132	151
7/23	152	156	177	162	151	154	152	151	155

(continued)

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

TABLE A6. CONTINUED

Date	Groundwater Elevations, Plots								
	1	2	3	4	5	6*	7*	8*	9*
	cm								
7/25	188	186	192	179	171	175	168	164	161
7/26	176	181	183	172	152	175	168	169	165
7/27	186	174	179	178	169	170	175	171	175
7/28	182	177	185	163	136	168	166	164	162
7/29	180	175	178	165	165	164	159	153	155
8/ 2	148	157	164	140	140	147	139	138	148
8/ 3	160	163	165	159	150	162	153	163	159
8/ 4	160	167	166	159	157	161	160	151	183
8/ 8	152	157	153	152	150	148	139	150	145
8/10	153	155	158	154	145	147	149	157	143
8/11	154	163	161	150	152	164	149	149	156
8/12	144	155	159	143	143	148	146	159	155
8/16	127	126	134	127	132	127	126	126	128
8/17	132	135	139	128	129	130	125	130	122
8/19	127	146	143	122	123	142	140	130	153
8/20	140	130	138	136	131	131	126	130	134
8/21	141	147	145	134	140	149	143	149	135
8/22	148	154	161	146	149	152	143	157	145
8/23	171	172	169	168	154	161	166	159	144
8/24	172	175	171	189	162	163	176	163	176
8/28	151	158	145	144	148	152	141	138	135
8/30	152	154	167	146	139	159	153	146	144
9/ 1	147	160	150	143	139	145	146	137	128
9/ 3	141	144	150	131	140	141	137	141	153
9/ 5	133	141	141	316	135	136	129	133	130
9/ 7	134	145	146	131	137	139	132	138	135
9/10	118	121	133	132	123	125	117	117	116
9/12	131	137	138	133	134	136	126	121	129
9/13	166	174	173	159	152	166	156	160	158
9/14	152	173	167	159	145	151	160	156	155
9/18	152	160	151	144	151	153	141	146	146
9/19	167	169	169	160	159	155	159	158	153

* These plots contain subsurface drainage tiles.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE

TABLE A7. 1978 GROUNDWATER ELEVATIONS WITH RESPECT TO THE REFERENCE LEVEL.

Date	Groundwater Elevations								
	Plots								
	1	2	3	4	5	6*	7*	8*	9*
	cm								
6/ 5	152	150	154	146	150	147	145	148	147
6/ 7	165	161	158	174	162	151	144	148	141
6/ 9	165	153	159	159	143	146	152	147	139
6/12	163	153	163	144	155	150	148	149	143
6/14	163	167	161	147	160	143	159	151	148
6/16	165	170	159	162	160	153	158	154	147
6/17	169	162	158	170	161	151	159	156	145
6/19	151	143	149	147	147	140	143	138	132
6/20	170	154	154	185	153	149	165	151	143
6/21	178	166	173	188	175	163	185	161	156
6/26	142	143	140	142	148	143	144	142	146
6/28	132	127	132	120	126	122	143	121	135
7/ 5	132	126	138	118	137	138	136	131	122
7/ 6	186	176	174	180	154	160	158	156	153
7/ 7	181	170	166	188	158	149	168	156	147
7/10	150	144	140	150	134	131	133	124	131
7/12	135	137	139	135	130	124	130	121	121
7/14	171	170	169	171	157	167	171	151	169
7/18	107	112	119	99	116	93	155	105	120
7/21	117	123	129	113	116	117	109	109	115
7/22	115	116	128	102	119	116	123	111	112
7/25	113	116	129	100	101	93	103	99	100
7/31	103	104	104	85	90	95	87	93	97
8/ 1	111	111	111	100	87	89	102	87	101
8/ 2	105	111	110	105	100	103	94	96	100
8/ 3	119	116	112	110	103	102	112	97	97
8/ 4	123	118	111	116	113	107	109	109	102
8/ 6	72	120	98	59	84	86	94	81	93
8/ 9	92	122	98	59	83	85	95	89	95

(continued)

BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

TABLE A7. CONTINUED

Date	Groundwater Elevations								
	Plots								
	1	2	3	4	5	6*	7*	8*	9*
	cm								
8/11	72	121	96	89	83	87	92	90	100
8/15	93	106	116	89	101	103	85	80	88
8/16	118	124	129	59	103	105	125	106	98
8/28	109	65	101	72	97	99	86	85	95
9/ 5	103	103	97	92	99	101	78	94	110
9/ 7	107	105	99	94	101	103	83	96	111
9/ 9	82	88	89	85	96	98	89	96	87
9/10	91	93	95	78	95	97	93	91	89
9/19	143	142	136	105	136	138	156	141	141
9/21	150	145	139	108	134	136	155	139	145
9/27	131	146	147	154	149	151	189	157	171
9/29	133	148	154	158	154	158	194	155	155

* These plots contain subsurface drainage tiles.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.) (4-76)